Mosquitoes — no. 24

Culicine no. 241

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NUMBER 4

MOSQUITO INTERMEDIARY HOSTS OF DISEASE IN AUSTRALIA AND NEW GUINEA

By
FRANK H. TAYLOR, F.R.E.S., F.Z.S.

Issued by
THE SCHOOL OF PUBLIC HEALTH AND TROPICAL MEDICINE
(UNIVERSITY OF SYDNEY)
COMMONWEALTH DEPARTMENT OF HEALTH

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FOREWORD.

THE conditions associated with war have brought into prominence all aspects of control of infectious diseases in Australia and surrounding territories. This applies particularly, because of the areas principally concerned, to diseases borne by insect vectors—especially mosquitoes.

It has become, therefore, of urgent importance to bring together in one volume the accumulated results of many years of study by many devoted persons in Australia.

In this work, Mr. Taylor has taken a prominent and very energetic share.

The School of Public Health and Tropical Medicine has been the recognized Australian centre for this branch of applied medicine.

It is appropriate that at this time, and from this School, should be issued a reference work on the mosquito intermediary hosts of disease in Australia and New Guinea.

J. H. L. CUMPSTON, M.D.,
Director-General of Health.

Canberra, A.C.T.
6th May, 1943.

PREFACE.

The purpose of this publication is to give as concisely as possible a description of the essential morphology of the adults, pupæ, and larvæ of the various species of mosquitoes, so far as we are aware, concerned with the transmission of disease, followed by practical details of control of the larva and adult.

I plead guilty to the crime of piracy. Much of the description of the morphology of the tribes Anophelini and Culicini has been drawn from three sources—Christophers and Barraud, Fauna of British India, Diptera, Culicidæ, and Edwards, Genera Insectorum, Fasc. 194. I have not been able under present conditions to ask for formal permission from the authors and publishers to use the material in these three volumes, for which I tender my warmest thanks. Had I written those sections myself they must, of necessity, have been but a paraphrase of what I have used, for such descriptions are standard.

My very sincere thanks go to Brigadier Gordon Covell, C.I.E., M.D., etc., who gave me permission to use any passages I wished from his book. He saved me many weary hours of writing.

I am grateful to Dr. A. J. Metcalf, Chief Quarantine Officer (General), Sydney, for his permission to use his notes on sulphur fumigation.

It will be seen from the "Contents" that I have endeavoured to make the publication as complete as possible. It is possible that some relevant work has been overlooked; this is done inadvertently, and pardon is asked.

It is, as far as my knowledge goes, the first occasion that a book of this nature has been published in any language.

Although I have included some keys to adults and larvæ, I am of opinion that such should never be used by any but specialists. I quite agree with Gater* when he wrote "Unfortunately, it appears that the issue of keys more or less terminated taxonomic investigations in Malaya for some years. The identification of species came to be considered an easy matter which could be learnt by assistants and inspectors in a comparatively short period, and there was at one time considerable prejudice against systematic work."

Sinton† states: "In the construction of large engineering works, the engineer naturally tries to complete the projects as cheaply as possible consistent with technical efficiency, and often takes no heed of, or does not realize, the disastrous results to health and prosperity which may follow upon his operations." It is to be hoped that for the future the engineer will collaborate with the Health Authorities and not produce, as he has in the past, breeding places of mosquitoes wherever he goes. Anyone who has travelled by trains in Australia cannot be but struck by the enormous number of borrow-pits along both sides of many railway lines in all States.

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* Gater: "Aids to the Identification of Anopheline Imagines in Malaya", 1935, p. 9.

† *Ind. Med. Gaz.*, LXXI, 181.

The map showing the distribution of Anopheles in Australia is incomplete, because we know but little about this subject at the present time.

The one outstanding fact brought out by Service Publication No. 3, "Dengue", and this publication is the wide distribution of *Aëdes* (*Stegomyia*) *aegypti*. If an earnest endeavour were made, this mosquito could be eradicated from Australia within two years.

The illustrations of other authors have in several cases been acknowledged in the letterpress. Acknowledgment is gratefully made for Figs. 41, 49*b*, 50 to P. J. Barraud; for Fig. 49*a* to Bonne-Wepster and Brug; for Figs. 29, 30, 31, 32, 33, 35, 36, 37 to the late F. W. Edwards; for Fig. 21 to T. W. Kirkpatrick; for Figs. 22, 34, 66, 67 to Patton and Evans. Fig. 20 is modified from Patton and Evans. My sincere thanks are extended to Dr. A. B. Walkom, Director, The Australian Museum, for the loan of blocks duly acknowledged in the letterpress; to the Linnean Society of New South Wales, for the loan of the block for Fig. 28; to the *Australian Journal of Science*, for the loan of the block for Fig. 37. My cordial thanks are extended to Miss N. B. Adams and E. H. Zeck for their excellent drawings. I would also wish to thank the staff of the Australasian Medical Publishing Company Limited for the care they have shown in the printing of this publication, and to Dr. R. E. Murray for drawing the map of Australia showing the endemic areas of malaria and *Anopheles* distribution and assistance with Dr. G. F. Lumley in proof-reading. Also to Miss J. Jamieson, of this School, for the very careful way in which she typed the manuscript.

FRANK H. TAYLOR.

18th May, 1943.

CONTENTS.

INTRODUCTION.

Mosquitoes belong to the Order Diptera, or flies, since they possess but one pair of wings—the anterior pair. They belong to the family Culicidæ, which is divided into three subfamilies—Dixinæ, Chaoborinæ and Culicinæ. The last contains by far the greatest number of species throughout the world, and all those capable of transmitting disease. The subfamily Culicinæ is subdivided into three tribes, two of which, the Anophelini and Culicini, contain the disease-bearing species.

Various illustrations have been taken from standard works, also certain portions of the text have been copied, with due acknowledgment, from such works. There is no need to make new drawings when such are obtainable and which are known to be accurate in all details.

It is necessary, for determining the species of an insect, to have a full understanding of all entomological terms and to know where one may find and what are the various segments *inter alia*. A full knowledge of the literature and how to employ it is a *sine qua non*.

So that the taxonomy of the thorax may be made clear to those who may have occasion to use this section, I have taken the following notes and figures from Edwards (1941).

Mosquitoes, themselves flies, may be distinguished from all other flies by the position of the wing veins (Fig. 20), veins R_{2+3}, M_{1+2}, M_{3+4}, Cu_1 and Cu_2 being branched. No other flies possess this character.

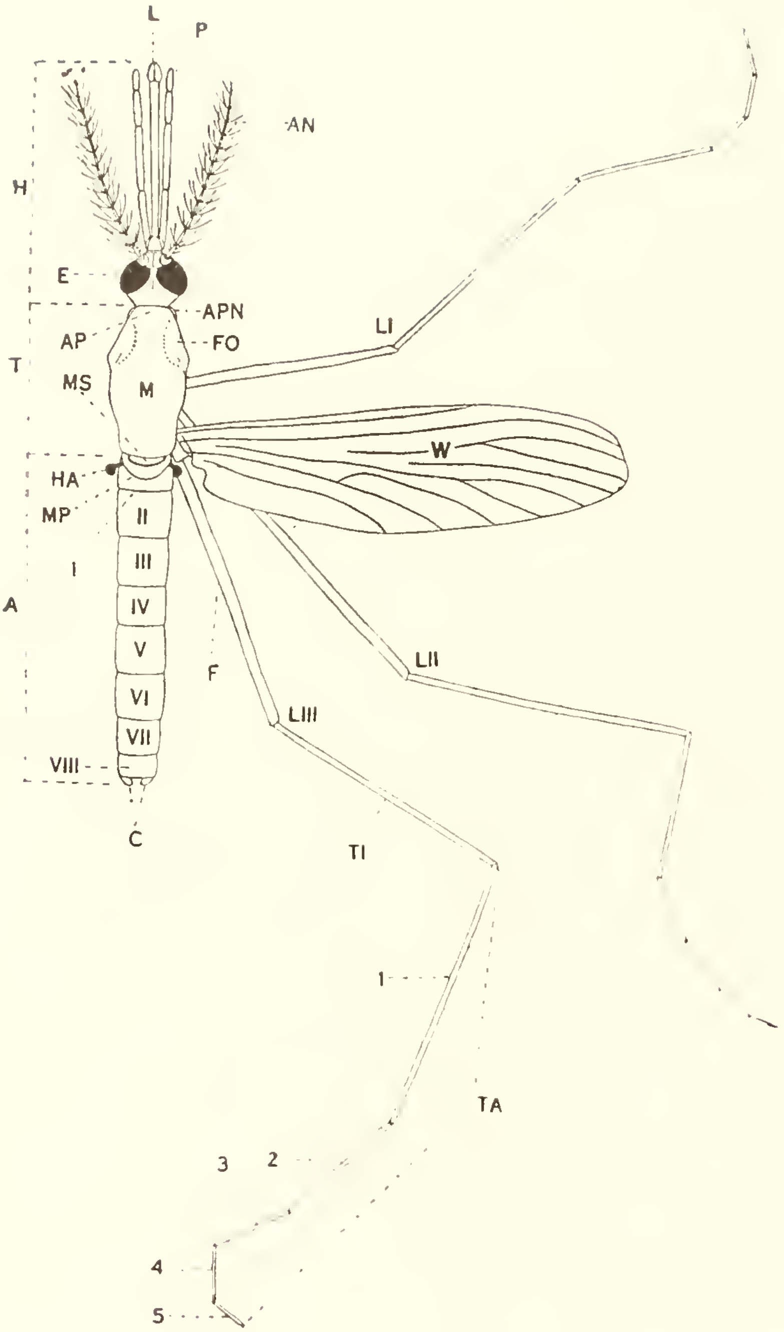

Diagram of a female, dorsal view. The left wing and legs have been omitted.

A, abdomen ; *An*, right antenna ; *AP*, anterior promontory ; *APN*, right anterior pronotum ; *C*, cerci ; *E*, left compound eye ; *F*, femur of right hind-leg ; *FO*, fossa ; *H*, head ; *HA*, left haltere ; *L*, labium (proboscis) ; *L.I*, right fore-leg ; *L.II*, right mid-leg ; *L.III*, right hind-leg ; *M*, mesonotum ; *MP*, mesopostnotum ; *MS*, mesoscutellum ; *P*, right palp ; *T*, thorax ; *TA*, tarsus of right hind-leg ; *TI*, tibia of right hind-leg ; *W*, right wing ; *I* to *VIII*, abdominal segments of corresponding numbers ; 1 to 5, tarsal segments of corresponding numbers on right hind-leg. (*After* Gater.)

ANOPHELINE ESSENTIAL MORPHOLOGY.

"Mosquitoes of the tribe Anophelini are commonly spoken of as the Malarial Mosquito, Anopheline mosquitoes, Anophelines, or 'Anopheles'. They resemble in their chief characters other mosquitoes, but are generally to be recognized at once by their spotted wings and their characteristic attitude when at rest on walls or other objects.*

"According to entomological definition, the Anophelini are distinguished from other mosquitoes by the long female palpi,† which are about the same length as the proboscis. In the male the palpi have the last two segments swollen and somewhat flattened, forming a characteristically shaped club not unlike the head of a golf-club, which appearance, together with the spotted wings and attitude, usually suffices to distinguish the males of Anophelini from those of other mosquitoes.

"The attitude of Anophelini when resting is very characteristic and is often referred to. Both in Culicini and Anophelini the fore and mid-legs are usually placed with the sharply flexed tibio-femoral joint directed upwards and the last tarsal segment or so only resting on the supporting surface, so as to give, with the first two pairs of legs, four *points d'appui*, more or less corresponding to the corners of a square; these legs form four approximately equal arches, supporting at a central point the weight of the body. In *Culex* the body is so slung as to be horizontal, the coxæ of all the legs being equally distant from the supporting surface, whereas in Anophelini the body is strongly tilted downwards at the head-end, each pair of coxæ from before backwards being progressively further away from the supporting surface. Taken in conjunction with the shape of the body, this causes the abdomen to point markedly away from the surface and the whole body to form with this an angle which may even approach 90° (Fig. 1). The hind legs as a rule take little or no part in supporting the body, though they are often placed so as to touch the supporting surface, and even at times are used to give support. As also in some Culicini, these legs are very commonly held in the air, often high above the abdomen.‡

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* Actually many species possess entirely unspotted wings. The commoner species in the tropics, however, mostly have spotted wings, though sometimes in dark species the pale spots are very small, and scarcely distinguishable without a lens.

Some Tipulidæ (small crane-flies) and Chaoborinæ (proboscis-less mosquitoes) may show a similar resting attitude, but no other Culicidæ. Some Anophelini, on the other hand, have a somewhat *Culex*-like attitude, though a typical hunch-back (*Tæniorhynchus*-like) attitude is practically confined to the rare and aberrant South American genus *Chagasia*.

† During life the palpi of the female (except when the insect is feeding) are held closely approximated to the proboscis, so that the two palps and the proboscis give the effect of a single organ. In the living condition all that an examination under a lens may show, especially when the palps are thin and delicate, is that, in Anophelini, the finger-like or bud-like palpi seen at the base of the proboscis in culicine mosquitoes are not to be made out. When the insect is dead, and the tissues somewhat dried, the palpi separate, and these organs, with the proboscis, may give a trident-like effect (Fig. 1).

‡ In the female anopheline the tip of the labium and the palpi are brought so close to the object rested upon that they are almost in contact with it. The tips of the tibiæ of the fore legs, which, both in Anophelini and Culicini, reach to a level slightly below the head, are in Culicini so situated as to lie behind the head, whereas in Anophelini they are in front of the head, and in side view usually cross the line of the proboscis or are entirely in front of this. The mid-femora and tibiæ, which in *Culex*, in lateral view, cross the line of the abdomen, are usually, in Anophelini, entirely below this structure. Accentuating the distinction in attitude is the fact that the tarsus in Anophelini is usually relatively longer than in most Culicini, and the insect is, therefore, raised higher.

"The exact angle made by the insect's body with the supporting surface varies considerably not only with the species, but also according to whether the insect is resting on a vertical or horizontal surface or suspended from the latter, and, also, whether the insect is in a fed or gravid condition or not, or is fresh and lively or weak . . .

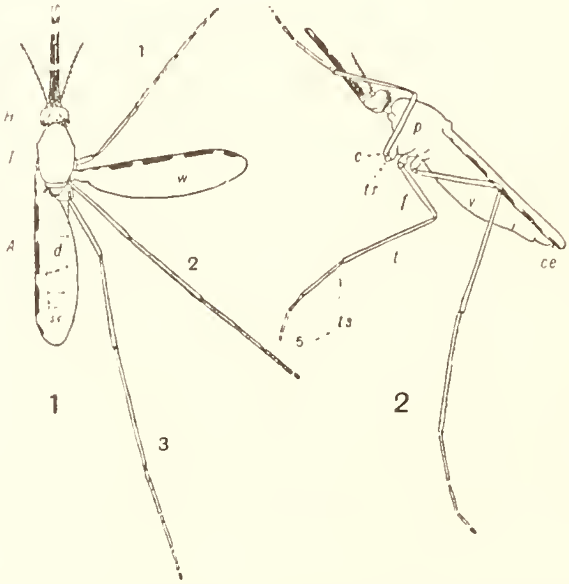


Fig. 1.—General structure and resting attitude of living insect: 1, dorsal view of unfed ♀, showing position of wings folded and expanded; 2, lateral view of an anopheline (*A. annularis*) resting on a vertical surface. The specimen is engorged to some degree.

A, abdomen.
c, coxa of fore leg.
ce, cercus.
d, dorsum of abdomen (tergites).
f, femur.
H, head.
p, pleura.
T, thorax.
t, tibia.
tr, trochanter of fore leg.
ts, tarsus (segments 1–5) of mid-leg.
w, wing.
v, venter of abdomen (sternites).
1–3. fore, mid- and hing leg respectively.

"Equally characteristic of the tribe is the straight configuration of the body, the head and proboscis being nearly in the same line as the rest of the body. As a consequence, the angle formed by the under surface of the head with the prosternal region of the thorax is much larger in anopheline than in culicine mosquitoes (120° as against 90° or less). The attachment of the abdomen, further, is such that its axis forms about a right angle with a line joining the middle coxa with the middle of the dorsum of the thorax, whereas in culicine mosquitoes the angle is much smaller, in some cases less than 45°. Even when the attitude is somewhat *Culex*-like, e.g. in *A. culicifacies*, the straight configuration of the body still largely holds good.

"The spotting of the wings* is very characteristic of Anophelini, though not entirely confined to this tribe of Culicidæ, whilst many species of the tribe do not show it. The common European species *A. maculipennis* has wings spotted with small dark spots due to aggregations of scales on the wing-field; but the more usual and typical form of spotting, and that which

* For a study of the wing-spotting in *Anopheles*, see Christophers, *Ann. Trop. Med. and Par.*, VII, 1913, p. 45.

is seen in the majority of species, is due to pale spots on the costa and wing-veins caused by the veins being alternately clothed with dark and pale scales. The effect is to give rise to linear dark or pale spots, these appearing either as pale spots on a dark ground or *vice versa* though about an equal amount of pale and dark is common.

Fig. 2.—Resting attitude. Above, *Anopheles*; below, *Culicini*.
[Photo.—Shell Co. of Australia, Ltd. From *Aust. Mus. Mag.*

"Other features characteristic of the adult insect are noted under the Key to Genera and Subgenera and in the systematic part of the work. The most important are the bar-shaped scutellum, with the scutellar hairs forming an unbroken row, the single large claw on the fore legs in the male, and the absence of a regular imbricated vestiture of scales on the abdomen, as is universal in Culicini. Though numerous scales may be present in some Anophelini on the dorsum, the sternites are always in large part bare.

"So far as is known, the median acinus of the salivary gland in Anophelini is saccular, thus differing from *Culex*, where it is tubular, with a narrow duct. The female carries a single spermatheca, three being the usual number in Culicini, though a single spermatheca may be present in some forms.

"The larvæ of Anophelini are distinguished from the larvæ of other mosquitoes by the absence of a supporting tube (siphon) to the spiracular apparatus,* by their horizontal attitude when at rest or moving at the surface of the water, and by the

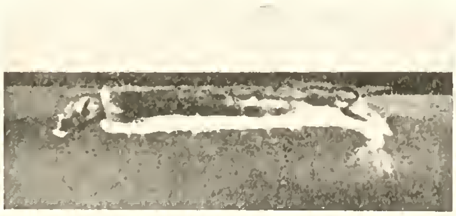


Fig. 2*a*.—Feeding and resting position of *Anopheles* larva.
[Photo.—Shell Co. of Australia, Ltd. From *Aust. Mus. Mag.*

* The whole of the respiratory apparatus of *Anopheles* is represented by the parts at the tip of the siphon in Culicini.

fact that, when supported at the surface, their bodies are actually in contact with the surface-film by means of their abdominal float-hairs, which cause little dimples in the surface. A further character of the larva is the ability to rotate the head through 180° to allow of feeding at the surface. They are also peculiar in possessing eversible organs on the thorax (eversible organs of Nuttall and Shipley), and the large hairs are for the most part pinnately branched in one plane. The larvae of Anophelini are found in nature almost exclusively in natural waters and, unlike many Culicini, are rarely found in pots and other domestic collections of water.

"The egg is also characteristic, being usually boat-shaped, with a demarcated upper surface and laterally situated floats."

The number of known species in the world is about 170, of which six species, one subspecies and one variety are known from Australia.

CLASSIFICATION.

"The classification adopted in this volume is, as regards the genera and subgenera, that given by Edwards in his most recent work, which appears most satisfactorily to display what is known up to date of the affinities of the main groups and of the aberrant forms of Anophelini. Of the three genera recognized, the genus *Anopheles* . . . includes the great majority of species in the tribe. Structural differences such as can be used satisfactorily for classification have for the most part been brought to light only comparatively recently. The classification of Theobald and others on scale-structure has shown itself, in the course of time, inadequate and misleading, chiefly because it is evident that scale-structure in the tribe has progressed on somewhat parallel lines in a number of distinct phylogenetic stems. This classification has now been abandoned for others of a more satisfactory character.

"*Classification by Male Genitalic Characters.*—After separation of the genera *Chagasia* and *Bironella* on the male tarsal claws, etc., the most satisfactory primary subdivisions appear to be those given by the male genitalic characters, i.e., on the number and arrangement of the parabasal spines. Such subdivisions are generally agreed to be most conveniently treated as subgenera. They are not only consistent with the general structure and ornamentation of the adult (Christophers, 1913, 1915, 1924), but also accord closely with subdivisions based on the recent work on pharyngeal characters by Sinton and Covell (1927) and Barraud and Covell (1928, 1929) and those based on the pleural hairs and other characters of the larva as recently shown by Puri (1929, 1931).

"The characters and arrangement of the parabasal spines on which these subgenera are founded are sufficiently indicated in the Keys to Genera and Subgenera . . ."

The Australian Anopheles belong to the groups *Anopheles* and *Myzomyia*.

The pharyngeal armature of the Australian species is not dealt with in this publication for the reason that those people for whom it is written have not the equipment nor the training to make such dissections.

"CLASSIFICATION OF ANOPHELINI.

Genus or Subgenus.	Group.	Adult Characters. (General.)	Parabasal Spines. (♂).	Pharyngeal Armature. (♀).	Long Pleural Hairs (Larva).
Genus *Chagasia*	—	Distinct.	Peculiar.		Extra hair.
Genus *Bironella*	—	Distinct.	Peculiar.		
Genus *Anopheles*— Subgenus *Stethomyia* ..	—	Distinct.	One.	Absent.	
Subgenus *Anopheles* ..	*Anopheles.* *Arribalzagia.* *Christya.*	Less than four main costal spots.	Two.		All simple.
Subgenus *Nyssorhynchus* ..	*Nyssorhynchus.* *Myzorhynchella.* *Kerteszia.*		One basal, two on coxite.	Single row, recurved.	
Subgenus *Myzomyia* ..	*Neomyzomyia.* *Pseudomyzomyia.* *Paramyzomyia.* *Myzomyia.* *Neocellia.* *Cellia.*	Four main costal spots.	Four to five in one group.	Single row. Double row.	Some at least feathered.

"*Classification by Pupal Characters.*—The pupal characters of a considerable number of species have been described by Senevet. As a general rule division into *Anopheles* and *Myzomyia* is indicated by the paddle-hair (short and straight in *Anopheles*; long and hooked in *Myzomyia*) . . ."

CHARACTERS USED IN IDENTIFICATION AND CLASSIFICATION.

ADULT CHARACTERS.*

The nomenclature used for parts of the body is shown in Fig. 1. The different parts are considered more in detail below.

Head.

The nomenclature of the head-structures is indicated in Fig. 3. The *head-scales*, which cover the occiput and most of the vertex between the eyes, are of a single type, being erect, narrowly fan-shaped, truncated, and often slightly notched, giving them a forked appearance under a low power. They usually have about 12–15 striations, which extend nearly to the base of the scale. The scales vary somewhat in shape, etc., on different parts of the head, and only outstanding peculiarities are given in the descriptions in this volume. Almost always the head-scales are dark at the sides and back of the head, and become pale or white over the front of the vertex, forming a conspicuous white patch of varying extent in this situation (*pale vertical spot*).

Anteriorly between the eyes is a somewhat triangular area (*interocular vertex*), passing forward to about the base of the antennæ. The head-scales are usually continued on to this as overlapping fusiform scales, which make a conspicuous line of scaling along the inner margin of the eyes (*ocular scales*). Internal to the ocular scales on each side is a line of setæ, often milk-white (*vertical setæ*). The vertical setæ in front commonly terminate in a cluster of elongate setiform pale or white scales, usually more or less curled at the ends, which pass forwards over the clypeus. The long setiform scales, with the other vertical setæ, and the ocular scales, together form the so-called *frontal tuft* characteristic of most anophelines.

Around the margin of the eyes are the dark *ocular chætæ*, and distinct from these ventrally below the eyes a close-set line of hairs, often giving the effect of a beard—the *postgenal hairs*.

Antennæ.

These consist of a globular basal segment (*torus*†) and a beaded series of flagellar segments (13 in the ♀, 14 in the ♂),

---

* Among general characters of the adult which should, perhaps, be mentioned are size and colour. Anopheles of the group Myzomyia are as a rule distinctly small. The index used for designating size in this volume is the length of the wing; this is about 3 mm. for small species, 4–4·5 mm. for moderate-sized species, and 5–6 mm. for very large species.

Coloration in the group varies from a lightish grey or fawn to shades of brown practically amounting to black, and, though subject to some variation in the same species, is often very helpful in identification. Sometimes specimens may show more pigmentation than is usual with the species, with an increase in the extent of dark markings on wing, tarsi, palps, etc., and often with bridging of costal spots and other anomalies of wing-ornamentation (*melanism*). A contrary effect is seen where the dark markings are abnormally restricted and spots normally present obliterated, or pigmentation may be defective in a capricious manner or almost entirely absent (*hypomelanism*).

† True second segment, the first being a narrow basal ring, only to be made out, as a rule, in cleared and mounted preparations. The torus is also called the pedicle, and the ring-piece at its base the scape.

Fig. 3.—Nomenclature of parts of the head: 1, head of ♀, showing palpi, antennæ, etc., the palp of the side shown denuded of scales: 2, ditto of ♂; 3, head, showing arrangement of scales and hairs on vertex; 4, lateral view of head; 6, tip of mandible; 7, tip of maxilla.

A, antenna.
Ab, apical pale band.
apg, anterior portion of postgena.
Bb, intervening dark area between apical and subapical pale bands.
C, clypeus.
Cb, subapical pale band.
F, frons.
Hs, head-scales.
L, labium.
Lb, labella.
m, tip of mouth-parts lying in labial sheath.
O, compound eye.
Oc, ocular chætæ.
Op, occiput.
Os, ocular scales.
P, palp.
pg, postgena.
pgc, postgenal chætæ.
t, torus.
V, vertex.
Vc, vertical chætæ.
Vt, vertical tuft.
1–5, segments of palpi (♂ and ♀).

which form the antenna proper. In the male the torus is very large and the antenna markedly plumose, due to whorls of long hairs arising from paired plates on the segments. In the female the torus is smaller and the hairs are shorter, arising in a ring from the bases of the segments.

In the male the antenna, including the torus, is devoid of scales in all Indian species, except on the first flagellar segment,

where some scales are often present, usually dark. In the female the torus may be bare or, in many species, may carry a few minute scales, often difficult to see. Scales are commonly present on the first or second flagellar segment or, in some species, on a number of flagellar segments in the female.

Female Palpi.

The normal arrangement of the segments is shown in Fig. 3. The basal (first) segment is small and vestigial, and fused with the succeeding long segment. The relation of the length of segment 5 to that of 4 gives the *palpal index*, which varies from 0·3 to 0·7.

Scales are present on all the surfaces except the inner, which is bare of scales along the whole length of the organ; chætæ, or stiff hairs, are usually present on the apical segment and in a line along the ventro-internal border of other segments. The scales may be appressed over the whole organ, when the palpi appear long and *thin*; or commonly the basal portion, or greater part, of the first long segment has erect scales, those over the rest of the organ being more appressed; or the whole organ may be covered with erect scales, giving it a *shaggy* appearance.

Ornamentation of the palpi is mainly in the form of pale scales forming bands of various width at the apex and at joints 3–4 and 2–3. When the apical segment is short it is usually completely involved in the apical pale band, the palpi showing three bands, including the apical. When the apical segment is long it frequently carries a dark band, and the palpi show four pale bands. In species normally showing three bands it is not uncommon for individuals to show a variation in the presence of a dark band on the apical segment and a resultant 4-banded palp. This is unusual, however, except where the apical segment is long (e.g. in *A. superpictus*).

In addition to bands, there may be patches of pale scaling on the dorsum of some of the segments, especially segment 3 (*speckling* of the palps). Specimens may sometimes show a more diffuse paling along the length of the segment which is often not of specific character, and may be referred to as *frosting*.

Male Palpi.

These are composed of five segments, including a vestigial basal segment, as in the female, but with segments 2 and 3 separated by an incomplete joint only. Segments 4 and 5 are expanded and somewhat flattened, usually with thickening also, of the apex of segment 3. The junction of 4 and 5 is commonly more like a suture than a joint, but in some species the two are much more clearly articulated and the segments somewhat constricted at the junction.

Except where the scales at the extreme base, or at some other points, may be erect, the organ is covered on its outer aspect with appressed scales which give it its ornamentation. Long hairs arise from the swollen apical end of segment 3, and a line of hairs, which may be a single or several rows thick, is usually continued along both borders of segments 4 and 5 or may be wholly or partly lacking on the latter (*marginal hairs*).

The types of ornamentation can be seen from the descriptions of species. Care should be taken in examining this organ in the dried specimen, as it is often twisted, and misleading appearances may be seen should the unornamented lower (inner) surface of the club be uppermost.

Labium or Proboscis.

The labium is generally uniformly dark, except the labella, which are usually of a lighter colour. In a few species the apical half or so is light or golden, or there may be a diffuse pale patch beneath or at the sides towards the apex (*tache*). These effects are often only clearly visible in certain lights.

Mandibles and Maxillæ.

Normally contained within the sheath-like labium are the fine chitinous mandibles and maxillæ, along with the stylet-like labrum and hypopharynx. The mandible is expanded at its termination into a triangular plate, one edge of which carries very fine teeth, usually, in Indian species, about 25–30. The maxillæ have curved, sword-like ends, usually with about 13–15 teeth, larger than those of the mandible, which become progressively smaller and more minute towards the end of the organ. Examination of practically all the Indian species has shown but few differences in species or variation from the characters given above, and reference to these organs is usually, for brevity, omitted from the descriptions.

Thorax.

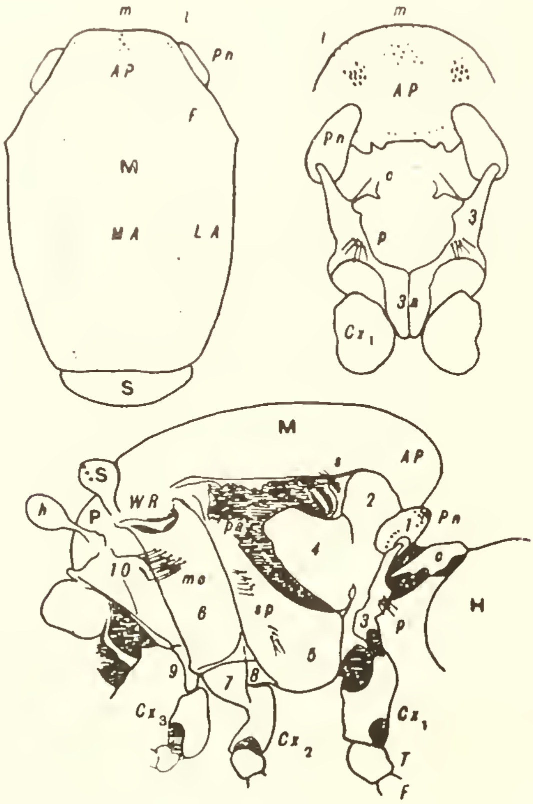
The general characters and nomenclature of the parts of the anopheline thorax are given in Fig. 4.

The *anterior pronotal lobes* (prothoracic lobes) commonly carry chætæ only, but may be furnished, in addition, with a tuft of erect scales (*prothoracic* or *pronotal tuft*). On the narrow chitinous propleuræ, lying on either side of the membranous area below the neck, are the *propleural hairs*. These may form a cluster of four or five or more, be reduced to two or one, or be entirely absent; they are of considerable systematic importance.

The mesonotum may be bare and shiny, with only large chætæ, but more usually the surface is to a certain extent tomentose, giving different effects, depending on the direction of the light-incidence. Frequently darker longitudinal lines are seen, especially on the denuded notum, but such appearances usually vary with the light-incidence, and reference to them is omitted in the descriptions. In a few species *eye-spots* are present. Most usually there is a vestiture either of numerous small hairs, of hair-like scales, or of true scales. Very commonly there is a somewhat lighter coloured *median area*, which in species with scales is usually more closely scaled, contrasting with the darker *fossæ* and *lateral borders* of the mesonotum, which are frequently devoid of scales or relatively so.

On the anterior promontory there is usually present a number of pale erect scales behind the head (*median scale-tuft*). More laterally, at the angles of the promontory, there may also be scale-tufts (*lateral scale-tufts*). In the latter situation the

scales are usually white above, and there are commonly conspicuous, often battledore-shaped, black scales below these on the anterior face of the promontory.

1.  2.

3.

Fig. 4.—Nomenclature of parts of thorax: 1, dorsal view of mesonotum; 2, anterior view of prothorax and mesonotum after removal of head; 3, lateral view of thorax.

AP, anterior promontory of mesonotum.
c, cervical sclerite.
Cx_1-Cx_3, coxæ of fore, mid-, and hind legs.
F, fossa of mesonotum.
F (lower figure), femur.
H, head.
h, halter.
l, site of lateral scale-tuft on anterior promontory.
LA, lateral area of mesonotum.
M, mesonotum.
m, site of median scale-tuft on anterior promontory.
MA, median area of mesonotum.
me, upper mesepimeral hairs.
P, Postscutellum (postnotum).
p, propleural hairs.
Pn, anterior pronotal lobe.
pa, prealar hairs.
S, scutellum.
s, spiracular hairs.
sp, upper and lower sternopleural group of hairs.
T, trochanters.
WR, base of wing.

Parts of pleuræ (membranous areas shaded):

1, anterior pronotum (anterior pronotal lobe).
2, postpronotum shown continued as narrow proepimeron to coxal articulation.
3, propleuron (episternum).
3*a*, basisternum of prothorax.
4, postspiracular area (mesothoracic anepisternum).
5, sternopleuron of mesothorax.
6, mesepimeron.
7, meron.
8, trochantin.
9, sternopleuron of metathorax.
10, metathorax.

The pilotaxy of the thorax is shown in Fig. 4. The propleural hairs have already been referred to. Of the other pleural chaetae, the *spiracular* are commonly from 0–5 in number; the *prealar* form a conspicuous tuft in some species, but are minute and difficult to make out in others; the *sternopleural* are usually divided into two groups, an upper and a lower, and consist of small as well as larger hairs; the *upper mesepimeral* are usually 15 or more in number and conspicuous. The lower mesepimeral on the epimeral plate separated from the upper group are usually absent, but are present in *A. barbirostris* and some other species. The postnotal (on the plate behind the anterior pronotal lobes) and the postspiracular (on the chitinization behind the anterior spiracle) appear to be absent throughout the tribe. These hairs, with the exception of the propleural hairs, do not appear to be of very great systematic importance and, as their exact number appears to vary in the same species, only outstanding characters, if such exist, are usually given in the descriptions. Scales are not infrequently present on the sternopleuron or mesepimeron, and their presence or absence may help in the differentiation of certain forms.

Wing.

The nomenclature of parts of the wing and of the venation . . . are shown in Fig. 5. In the descriptions, for brevity the longitudinal veins and their branches are indicated by numbers, e.g. 2, 2.1, 2.2 indicate respectively the stem, the anterior, and the posterior branch of the second longitudinal vein.*

" The length of the wing, measured from the origin of the costa to the level of the apex, is ordinarily, in Anophelini, about $2\frac{1}{2}$ times the length of the thorax measured from the anterior promontory to the back of the scutellum, but is proportionately more (up to three times or slightly over) in large-winged species such as *A. hyrcanus*. The greatest width, excluding the fringe, is usually slightly over $\frac{1}{4}$ the length; the wing in the male is slightly narrower, about $\frac{1}{5}$ the length. The subcosta joins the costa slightly under $\frac{2}{3}$ the length of the wing from the base (0·62–0·65 of the wing-length). The anterior forked cell in the female usually measures $\frac{1}{4}$ or slightly more of the length of the wing . . . The relative lengths of the two forked cells, measured along the posterior branch in each case, is the *forked cell index* (usually about 1·5, but reaching 2 in some species where the anterior forked cell is very long). The length of the anterior forked cell in relation to its petiole (from the bifurcation to the cross-vein) is often very variable in the same species, but may be used to give a general indication of the length of the cell. The forked cells are usually slightly shorter in the male.

* This nomenclature, which is in common use among workers on the Culicidae, has probably followed that given by Theobald (Vol. 1, p. 18). Theobald appears to have followed Skuse (*Proc. Linn. Soc. N. S. Wales*, III, 1889, p. 1763, pl. 40), his figure being a copy of that given by Skuse, who seems to have been the first to adapt to the wing of the mosquito the system of nomenclature in common use among students of the Diptera in the latter half of the nineteenth century. Among students of the Culicidae many of the cell-names and other unnecessary detail have gradually dropped out of use; all that is now necessary is given in the accompanying figure.

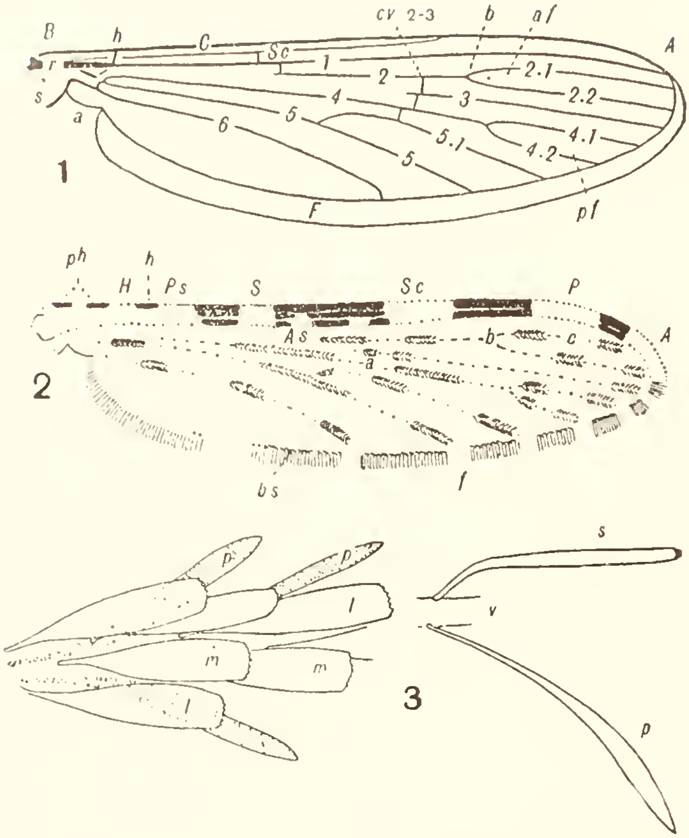


Fig. 5.—Venation and spotting of wing and nomenclature used: 1, venation; 2, usual situation of spots on wing (*Myzomyia*) and nomenclature used; 3, arrangement of scales on vein. Right, vein viewed from above; left, as a vein would appear in vertical section.

1. *A*, apex of wing.
   a, alula.
   af, anterior forked cell.
   B, base of wing.
   b, bifurcation.
   C, costa.
   cv2–3, cross-vein between vein 2 and vein 3; other cross-veins similarly, except humeral.
   h, humeral cross-vein.
   pf, posterior forked cell.
   r, remigium (or stem-vein).
   F, fringe.
   Sc, subcosta.
   s, squama.
   1, first longitudinal (Radius, R_1 of Comstock and Needham).
   2, second longitudinal (R_{2+3} of Comstock and Needham).
   2.1, anterior branch, second longitudinal (R_2).
   2.2, posterior branch, second longitudinal (R_3).
   3, third longitudinal (R_{4+5}).
   4, fourth longitudinal (Media, *M*).
   4.1, anterior branch, fourth longitudinal (M_1).
   4.2, posterior branch, fourth longitudinal (M_2).
   5, main fifth longitudinal (*Cu*).
   5.1, branch of fifth longitudinal (Cu_1 or M_4).
   6, sixth longitudinal (Anal, *A*).
2. *A*, apical pale area.
   As, accessory sector pale area.
   bs, border-scales.
   f, fringe-spot.
   H, humeral pale interruption.
   h, humeral dark accessory spot.
   P, preapical pale area.
   Ps, presector pale area.

"*Scaling of the Wing.*

"The general arrangement of scales on the wing-veins in the Anophelini is shown in Fig. 5, which shows the arrangement of scales on a convex vein as seen from above. The costa (up to the subcostal junction) and veins 1, 3, 5, and 6 are *direct* or *convex* veins, and the subcosta and veins 2 and 4 *reverse* or *concave* veins. On the upper surface of direct veins and the lower surface of reverse veins" (Christophers, 1923; Christophers and Barraud, 1924) "the scales are normally somewhat bat-shaped, often truncated, and with parallel striations; they have short, bent stalks and lie flat and parallel to the vein (*squame scales*). Those in the middle of the vein (*median squames*), are usually shorter and often narrower than those projecting laterally over the wing-membrane (*lateral squames*). On the lower surface of direct veins and on the upper surface of reverse veins the scales are longer, usually narrower and more pointed, with less numerous and less markedly parallel striations; their stalks are not sharply bent and the scales project at an angle from the vein (*plume scales*). As the apex of the wing is approached, the scales tend to elongate and to lose their distinctive characters, and the same applies to the greater part of the wing in some species.

"The broadest scales, as a rule, are on the inner third of the costa, subcosta, and vein 1. They are also about equally broad on the base of the stem of vein 5, but are distinctly narrower and usually less truncated on the remaining veins. The number of striations shown by the scales on the inner third of the costa, subcosta, or vein 1 is the *maximum striation* for the species.

"On the wing-border posteriorly are the special *fringe scales*, and at their bases are small, obliquely set scales (*border scales*), which may be dark, or light, or absent more or less extensively towards the base of the wing, according to the species.

---

ph, prehumeral dark accessory spot; may be divided into *inner* and *outer* by the prehumeral pale interruption.
S, sector, pale area.
Sc, subcostal pale area.

Between *A* and *P* is the *apical dark spot*; between *P* and *Sc* is the *preapical dark spot*; between *Sc* and *S* is the *middle dark spot*; between *S* and *Ps* is the *presector dark spot*.

a indicates the region of short pale spots due to the cross-veins: *b* is a bifurcation site: *c* is an example of a pale interruption dividing the dark length of branches of the forked cell into two spots on each branch.

Dark spots on the stem and branches of veins may usually be sufficiently designated by the terms apical and basal, or, in some cases, also middle, e.g., basal dark spot 2.1.

3. *l*, lateral squame.
m, median squame.
p, plume-scale (on under surface).
s, squame-scale (on upper surface of wing).
v, vein (in section).

The nomenclature used is that of Christophers (1933):

Costa.	Third longitudinal, 3.
Subcosta.	Fourth longitudinal, 4, 4.1, 4.2.
First longitudinal, 1.	Fifth longitudinal, 5, 5.1, 5.2.
Second longitudinal, 2, 2.1, 2.2.	Sixth longitudinal, 6.

Cross-veins, 2–3, 3–4, 4–5.

"*Ornamentation of the Wing.*

"The ornamentation of the wing is almost entirely due to scaling, and consists usually of alternate areas of dark and pale scales on the veins. For clearness the dark areas are here referred to as 'spots' and the pale areas as 'areas', usually with the prefix dark or pale, as the case may be, to aid the memory. The names used for spots and areas on the costa are shown in Fig. 5. These names are not difficult to remember, and greatly simplify reference and description. The spots on the wing-field in subgenus *Myzomyia* are also very regular and are, to a certain extent, referred to specifically. The spots in subgenus *Anopheles* are more individual, and have for the present been referred to in whatever seemed the simplest manner.

"Ornamentation at the base of the costa is highly important, the nomenclature here used being shown in the figure.

"Ornamentation of the apex and fringe are also extremely important. At the junction of vein 1 with the costa at the apex of the wing is the *apical pale costal spot*, always very clearly identifiable. Beyond this point is the scale-thickened wing-margin, merging into the fringe and referred to as the *wing-apex*; this is commonly ornamented by pale areas, at least at some of the vein-junctions. On the fringe at vein-junctions, and sometimes in other positions, pale *fringe spots* may be present. In subgenus *Anopheles* the appearance of fringe-spots tends to be rather capricious. In subgenus *Myzomyia* fringe-spots, if present at all, usually occur at all veins to 5.2, and in many species also at 6.

"In the male the wing often has rather more extensive pale areas and often the dark areas are less dark, so that the markings may appear less definite; in certain cases points given as diagnostic in the female are not intended to apply to the male.

"*Legs.*

"The parts of the leg are shown in Fig. 1. The coxæ may be devoid of scales; more usually the anterior pair at least carry some scales, which may be in conspicuous tufts. All the remaining segments, except sometimes the hind or middle trochanters, are clothed with small appressed scales, the colouration of which brings about such ornamentation as may be present.

"The femora are sometimes pale towards their articulation with the trochanters, the distance to which the paleness extends being given usually in terms of the breadth of the femur. They may be pale beneath or show other characters, often of some importance in identification. In a number of species the femora of the front legs may be swollen in their basal half. Both femora and tibiæ are often more or less extensively pale at their tips, a condition often referred to as *knee-spots*. In some species the femora and tibiæ, and sometimes some of the tarsal segments, are ornamented with defined patches or irregular rings of pale scaling (*speckling*). This is to be distinguished from an indefinite mottling sometimes seen.

"The chief ornamentation of the legs is usually in connection with the tarsal segments. They may be uniformly dark, or they may be marked with white or pale bands at the joints

(*banded tarsi*); bands may be *apical* only (i.e., at the tips of the segments, leaving the bases dark) or *apical and basal* (i.e., spreading across the joints).

"A common condition is for the terminal one or more segments of the hind legs to be *completely white*. Commonly the last three segments are completely white, with some portion of the preceding segment. Where a single segment only, or sometimes two, is completely white there are nearly always broad white bands at the tarsal joints above this . . .

"*Male Ungues.*

"In the male the mid- and hind legs carry a pair each of small simple hooks or claws, as do each of the legs in the female. But the fore legs are provided with a single large claw, having a spur about half-way along its length and a smaller process arising from the swollen base (*male ungues*) . . .

"*Abdomen.*

"The abdomen consists of eight visible segments. The first segment usually forms a somewhat transverse bar dorsally carrying long, outstanding hairs. The abdomen is usually spoken of as having a dorsal surface or *dorsum* (tergites) and a ventral surface or *venter* (sternites). The 8th segment in the male is rotated with the hypopygium, so that when rotation has taken place the apparent tergite is the sternite, and *vice versa*. Beyond the 8th segment in the male is the *male hypopygium*, of which the two large appendages, *coxites*, are the prominent feature. In the female the two small *cerci* are all that can be seen externally of the female *hypopygium*. The structures beyond the 8th segment in both sexes are often termed the male or female genitalia or *terminalia* (described in detail under 'Hypopygial Characters').

"The characters of the abdomen used in systematic work are chiefly connected with the scaling. The entire abdomen, with or without the coxites or cerci, may be completely devoid of scales. Frequently scales are present on the tergites of the last, or last few, segments; less commonly they are present on all the segments except the first. Besides the ordinary scaling, the tergites may show outstanding scales at the posterior lateral angles and, if numerous, these may form tufts (*lateral tufts*) . . . The sternites are usually free from scales, except commonly on the last segment or two. When present, scale-tufts are medianly situated towards the apex of the segment, *ventral tufts*; a tuft on the 7th segment only in the female is present in some species. Scattered scales over the venter occur in some species, and their presence is sometimes useful in differentiating certain closely related species.

"*Hypopygial Characters.*

"*Male.*—The general character and nomenclature of the male hypopygium in Anophelini are shown in Fig. 6.

"The *proctiger* (anal lobe) is mainly membranous, with an ill-defined chitinization (*ventro-lateral chitinization or paraproct*). The 9th sternite is narrow and crescentic and is linked to the tergite by a very narrow ribbon of chitin, which lies round the

base of the coxite externally. The 9th tergite is also narrow, forming a ribbon-shaped band dorsally at the base of the proctiger; at the lateral angles of the proctiger it is somewhat expanded, and in certain species is prolonged into a freely projecting spinous or knobbed process (*processes of 9th tergite*).

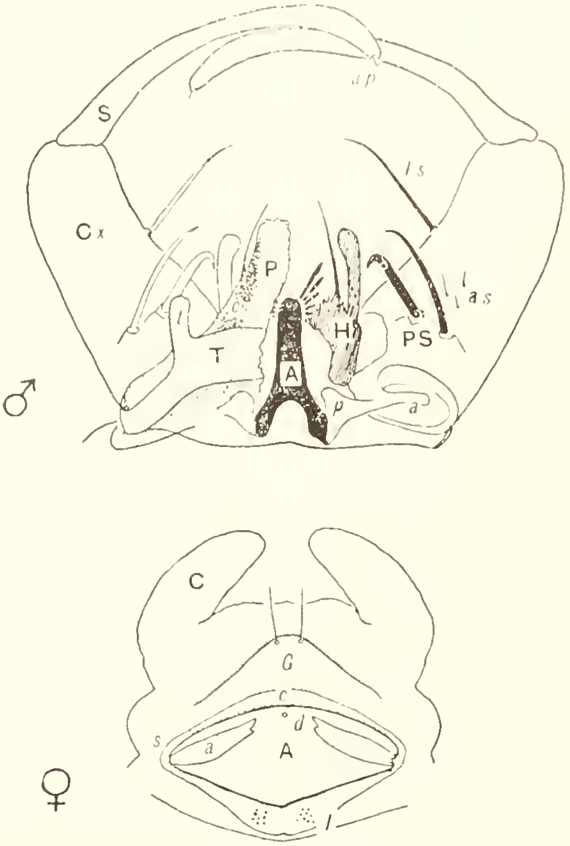


Fig. 6.—♂ and ♀ terminalia:—Upper figure: true dorsal view of ♂ hypopygium, right half of proctiger and 9th tergito, shown as removed. Lower figure: ventral view of ♀ hypopygium.

A, phallosome (ædeagus or mesosome).
a, apodeme of coxite.
ap, appendage of style.
as, accessory spines.
c, ventro-lateral chitinization.
Cx, coxite.
H, Harpago.
Is, internal spine.
P, proctiger.
p, chitinization of penis-cavity.
PS, parabasal spines.
S, style.
T, 9th tergite.
t, process of 9th tergite.
A, atrium.
a, atrial plate.
C, cercus.
c, anterior part of postgenital plate (cowl).
d, opening of spermathecal duct.
G, postgenital plate.
I, insula.
s, sigma (peri-atrial chitinization).

"The *coxite* (side-piece) is conically cylindrical in shape, not unlike a stumpy human thigh, convex externally but somewhat hollowed out at its base internally. The *style* (clasper) is very long and arcuate, with a small, terminal, spur-like appendage.

"The *parabasal spines* in subgenus *Anopheles* are two in number,* arising more or less distinctly from eminences, the inner spine shorter and stouter than the outer, both often

* Exceptions are found in the Palæarctic *A. algeriensis*, the Australian *A. stigmaticus* and *A. atratipes*, and the African *A. implexus*, which have only one parabasal spine, and in the European *A. claviger* (*bifurcatus*), which has three, the outer spine being duplicated.

recurved at the end. In subgenus *Myzomyia* there are usually five somewhat smaller thickened hairs rising directly from the surface of the coxite. These are arranged as shown in Fig. 7, four arising close together with the arrangement shown, and the fifth, a longer hair, at a little distance down the coxite. Hairs 1–4 are directed inwards, recurved at the ends and usually somewhat flattened, hair No. 1 being the shortest and hair No. 4 the longest. Hair No. 5 has more resemblance to an ordinary hair. One stout *internal spine* (or often two) on the inner edge of the coxite at a variable distance up this is usually present in subgenus *Anopheles*, but rarely in *Myzomyia*.

" Lying on the inner aspect of the coxite at its base, on either side, is the lobe-shaped *harpago*. In subgenus *Anopheles* the crest of the harpago may be somewhat irregularly divided into lobes, each carrying stout or sword-like spines, or the spines on the outer (dorsal) lobe are more or less fused into a club. In subgenus *Myzomyia* the harpago is conical or rounded, carrying a club-shaped process dorsally, and usually at its summit one largish hair (*apical hair*), with one or more smaller hairs (*accessory hairs*), according to the species.

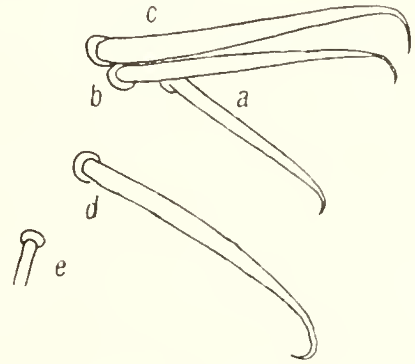


Fig. 7.

" Between the two harpagos is the phallosome (ædeagus, mesosome) . . . Though appearing straight when viewed from in front or behind, it is often seen, on a sideways view, to be much curved, a fact that has to be allowed for in making measurements. At the apex of the phallosome are usually, on either side, from three to seven or more leaflets. In some species these are absent. Of the leaflets, the first on each side is usually the largest, and the others diminish in size backwards. The larger leaflets, at least usually, are flat, more or less fusiform, blade-like or claw-shaped when properly displayed, and have usually a serrated thinner edge, the serrations being larger in some species. Seen edgeways, the same leaflets appear rod-like. To study the leaflets it is usually necessary to mount the phallosome separately and ensure proper flattening of the structures. Besides leaflets of the usual shape, there may be several or numerous small spicules in addition.

" *Female.*—The structure and nomenclature of the female hypopygium is shown in Fig. 6. In Anophelini the post-genital plate is of conical form and, so far as is known, throughout the tribe carries two apical, rather closely set hairs. The atrial plates are well marked. Lying along the lower part of the

opening posterior to the 8th sternite is a narrow transverse chitinization, sometimes almost membranous, the *insular plate* carrying on either side the *insula*. The insula consists of two small islets, of from 9–15 hairs each, on either side of the middle line. Very few distinctive differences occur, though it is possible in some cases the number of insular hairs may be a specific character.

"As there is practically nothing specific, so far as yet ascertained, about the female genitalic characters, these are omitted from the descriptions.

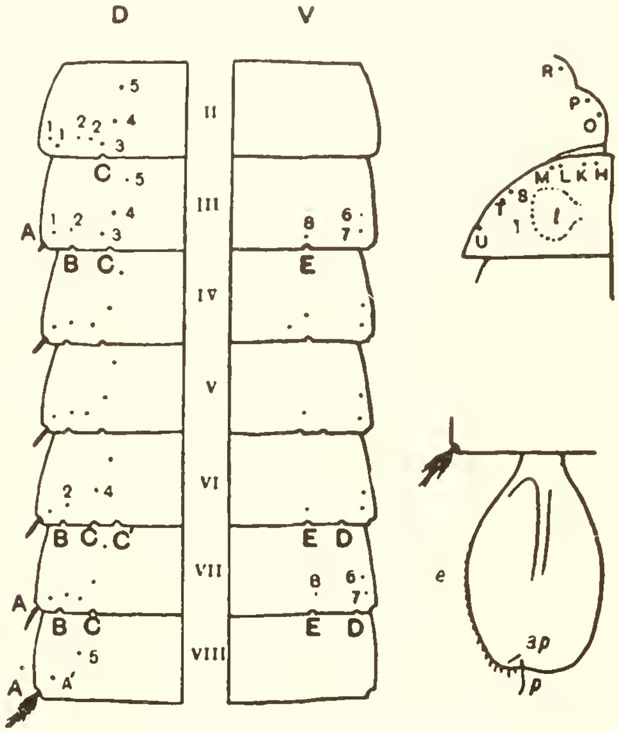


Fig. 8.—Hairs of abdomen and paddle of pupa. (*After* Senevet, with some modification.)

D, dorsum.
A, spine.
A′, accessory hair of spine.
B,C,C′, large dorsal hairs.
D,E, large ventral hairs.
1–5, small dorsal hairs (hairs I–V of Senevet).
6–8, small ventral hairs (hairs VI–VIII of Senevet).

V, venter.
H-U, hairs of metathorax and abdominal segment I, as given by Senevet.
t, dendritic tuft of abdominal segment 1.
e, external border of paddle.
p, paddle-hair.
ap, accessory paddle-hair.

"*Pupal Characters.* (Fig. 8.)

"The external structure of the pupa in Anophelini has been especially studied by Senevet, whose nomenclature is here followed. The characters that have been made use of in description are: the respiratory trumpets, the paddle, the abdominal (and metathoracic) chætotaxy.

"*Respiratory Trumpets.*—The respiratory trumpets in Anophelini are short, more or less sessile, truncated at the end, and with a very wide opening. Though the trumpets show differences in shape and appearance, no very definite description of these has so far been attempted, except for certain American and African species.

" *Paddle.*—The paddle in Anophelini is more or less oval in shape, with a median longitudinal midrib which may, or may not, extend to the margin of the paddle. At the apex of the paddle is a short, usually more or less hooked *paddle-hair*, and a little above the origin of the paddle-hair on the paddle is a smaller hair (*accessory paddle-hair*). On the external border may be present a series of denticles or teeth. Both the external and posterior border may carry small hairs on some, or all, of their extent.

" The position of the accessory paddle-hair is characteristic of the Anophelini ; in the genus *Culex* it is also present, but placed beside the paddle-hair, while in other Culicini it appears to be absent. The paddle-hair in subgenera *Anopheles* and *Nyssorhynchus* and group *Neomyzomyia* of subgenus *Myzomyia* appears generally to be short and more or less straight ; in other groups of *Myzomyia* it is generally longer and hooked or curled.

" *Chætotaxy.*—At the lateral posterior angle of each of the abdominal segments III–VII is a stout simple *spine* (hair A). On segment VIII is a similarly situated spine with branches (*spine* of VIIIth *segment*). The other hairs present on the abdomen are shown in the figure.

" The presence of spines on the posterior corners of segments III–VII and of a branched spine on segment VIII is characteristic of Anophelini. In pupæ of other Culicini there is usually present a hair only, which does not arise quite at the angle, and is usually branched. The characters of the spine and the size and degree of branching of the different hairs on the various segments afford specific characters.

" Spine *A* is generally long and pointed in *Myzomyia* but is frequently short, massive, and blunt in subgenus *Anopheles*. Hair *C* on segments V–VII is usually simple in *Myzomyia*, bifurcate or branched in subgenus *Anopheles*. For details regarding the other hairs Senevet should be consulted. There is considerable variation in the number of branches shown by the smaller hairs, and these are not, therefore, dealt with in the descriptions unless they show outstanding characters.

" *Larval Characters.*

" The general nomenclature of the parts of the larva is shown in Figs. 9 and 10. Further details regarding the larval structures are given below. The notation employed for the hairs is that of Puri, 1925 ; differences from other authors, where they exist, will be found in the explanation of the figures.

" *Instars.*

" The characters given in synoptic tables of larval characters are those relating to the fourth or last instar.

" Larvæ of the first instar are minute, measuring about 1 mm. and very dark in colour. Those of the second and third instars have a similar appearance but are larger. The third ecdysis leading to the fourth instar occurs when the larva has grown to about half the length it will be when fully grown. Immediately after an ecdysis the head is quite pale and almost transparent ; later it becomes darker, and in the first three instars may be uniformly black.

" In the first instar the hairs of the head, including the frontal hairs, are for the most part simple and unbranched. On the dorsal aspect of the head is the *egg-breaker*. The palmate hairs consist of a single leaflet only. The comb consists of two parts—the *primary comb*, which has about 6–10 teeth, the longest in the middle, and anterior and ventral to this a comb-like arrangement of teeth, the *secondary comb*. The ventral fan is not developed as such, being represented by a cluster of appressed spines on the ventral aspect of the last segment, which, as shown by Lang, may show specific differences.

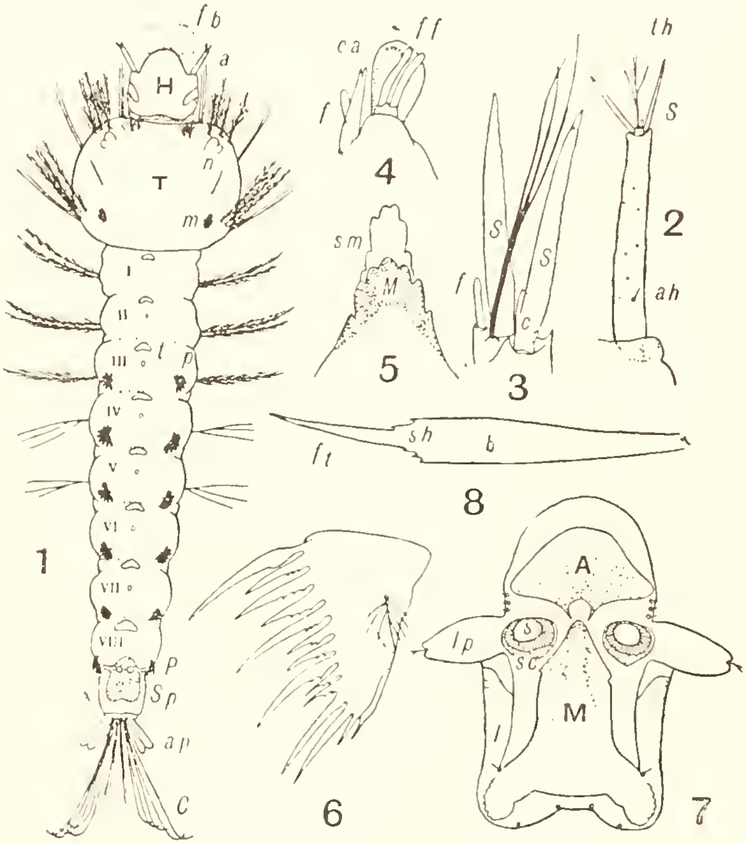


Fig. 9.—Larval characters : 1, dorsal view of larva ; 2, antenna ; 3, structures at apex of antenna (*after* Puri) ; 4, structures at tip of maxillary palp (*after* Puri) ; 5, mentum and submentum ; 6, pecten ; 7, spiracular apparatus, dorsal view ; 8, leaflet of palmate hair.

1. *a*, antenna.
ap, anal papillæ.
C, caudal hairs.
fb, feeding-brushes.
H, head.
m, hair No. 1 of metathorax (palmate hair).
n, notched organ of Nuttall and Shipley.
P, pecten (or comb).
p, abdominal segment, palmate hairs.
Sp, spiracular apparatus.
T, thorax.
t, tergal plates of abdominal segments.
I-*X*, abdominal segments.

2. *ah*, antennal hairs.
S, sabre.
th, terminal hair.

3. *c*, papilla.
f, spine.
S, sabres.

4. *ca*, cone-shaped appendage (bifid).
f, finger.
ff, Paired finger - shaped appendages.

5. *M*, mentum.
sm, submentum.

6. The hair shown is No. 6 (comb-hair of pecten-hair).

7. *A*, fan-shaped plate.
l, lateral plate of scoop.
lp, lateral papilla.
M, median plate of scoop.
S, spiracle.
sc, spiracular chitinization.

8. *b*, basal portion of leaflet.
ft, filament.
sh, shoulder-serrations.

" In the second and third instars there is an increasing degree of branching of the frontal and other hairs, and the palmate hairs show more leaflets. The comb is comparable in shape with that of the last instar, but shows fewer and less differentiated teeth. The maxillary palp is devoid of a subapical hair in the second instar, but this is present in the third . . . The dark collar on the posterior margin of the head grows in width in the earlier instars with the age of the larva, and may measure as much as one-third of the length of the head ; it remains of its original width in the last instar. In the second and third instars the head is proportionately narrower than in the last instar.

" *Colour and Pattern.*

" The head commonly shows a pattern due to *pigmented spots* connected with muscle attachments on the dorsum of the head ; they may be variously developed in different species and joined up or enveloped in *pigment-clouds*. The three anterior spots just behind the frontal hairs are commonly linked up by cloud, forming a transverse bar across the middle of the head ; the three median spots may be linked up to form a longitudinal median band ; or the posterior spots may form a large triangular patch ; there is also generally pigmentation along the V-shaped epicranial suture. The pattern is only of importance in certain cases where it may show specific differences in nearly related forms. All species breeding in certain situations (tree-holes, swamps, and wells) usually have almost completely dark heads.

" Markings of various kinds may be present on the thorax and abdomen ; silvery spots often form a V on the thorax and spots or lines on the abdominal segments. The colour of the larva is also largely characteristic for the species. As with the head-pattern, space will not permit of these characters being described unless there is some peculiarity, and for particulars of such Puri should be consulted.

" *The Head.*

" The various structures of the head are shown in Fig. 10.

" The *clypeal hairs* arise on the front of the frons-clypeus. They are here termed *inner*, *outer*, and *posterior* ; for brevity the lettering *ic*, *oc* and *pc* will be used respectively for these hairs in the descriptions. In subgenus *Anopheles* the bases of the inner hairs are close together, often nearly touching ; in *Myzomyia* they are wide apart, usually twice, or more than twice, the distance between the bases of the inner and outer hair of the same side. The preclypeal hairs arising from the preclypeus in front of the inner hairs should not be mistaken for these ; there is an inner pair, rather long and slender in some species ; the outer are minute, flattened, often truncated projections.

" The *frontal hairs* are three on each side ; when long, feathered, and reaching forwards to the level of about the bases of the inner clypeal hairs, they are referred to in the descriptions as normal. They are reduced and usually simple or with a few branches in tree-hole breeding species and in *A. turkhudi* (an Indian species). The *sutural* (8) and *trans-sutural* (9) are usually about as long as the posterior clypeal ; the former are

simple in most species, but may be branched and even feathered, the latter may be simple or feathered. The *subantennal hair* (basal hair) is usually a little shorter than the antenna, stout

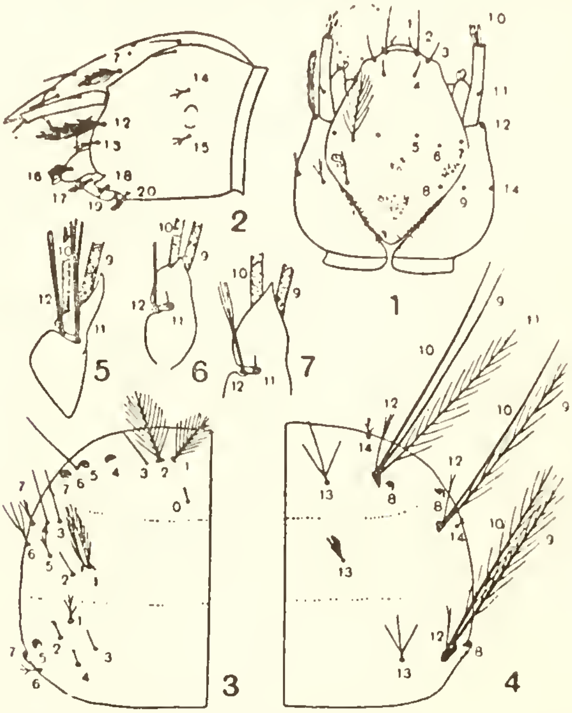


Fig. 10.—Hairs of larval head and thorax (*after* Puri) : 1, head, dorsal view ; 2, head, lateral view ; 3, thorax, dorsal view of left half ; 4, thorax, ventral view of left half ; 5–7, bases of pleural hairs of pro-, meso-, and metathorax respectively.

(The hair-numbers are those used by Puri ; unless otherwise stated, Martini's and Root's numbers do not differ.)

Head.

1. Inner preclypeal.
2. Inner clypeal (inner anterior of Puri).
3. Outer clypeal (outer anterior of Puri).
4. Posterior clypeal.
5. Inner frontal.
6. Middle frontal.
7. Outer frontal.
8. Sutural (inner occipital of Root).
9. Trans-sutural (outer occipital of Root).
10. Terminal hair of antenna.
11. Antennal hair (shaft-hair).
12. Subantennal (basal).
13. Postmandibular (sub-basal).
14. Orbital (dorsal eye-hair of Martini).
15. Infra-orbital (ventral eye-hair of Martini).
16. Hair on maxillary palp.
17. Hair on basal piece of maxilla.
18. Postmaxillary hair.
19. Hair on maxillary plate.
20. Submental hair.

Prothorax.

0. Dorsal submedian (not given by Martini or Root).
1. Inner submedian prothoracic } Shoulder hairs.
2. Middle submedian prothoracic } Shoulder hairs.
3. Outer submedian prothoracic } Shoulder hairs.

4–7. Lateral prothoracic hairs (No. 6 simple).

8. Ventral hair of lateral series.

9–12. Pleural hairs.

13. Ventral submedian.
14. Subcervical.

and feathered (normal); it is modified in tree-hole breeding species and in *A. turkhudi*.

" The *antenna* carries at some point on its shaft the *antennal hair*. In subgenus *Anopheles* this normally arises from the inner surface and is usually branched even if small; in subgenus *Myzomyia* it is a small, simple hair arising from the dorso-external surface. Tree-hole breeders (subgenus *Anopheles*) are anomalous in respect to this hair, and in them it may not only be simple, but also arise from the external surface. At the distal extremity of the antenna are a number of structures as shown in Fig. 9.

" The *mouth-brushes* (cephalic fans) show but little variation throughout the Anophelini . . . The *mandibles* are of complicated structure, but show few features of systematic importance. The *maxillæ* consist of a quadrangular plate forming the greater part of the maxilla and an externally situated conical appendage (*maxillary palp*). At the apex of the palp are the structures shown in the figure.

" The three leaflet-like appendages are peculiar to the Anophelini and connected with their method of feeding at the surface-film, with which these structures are in contact. The relative length of the *cone* and the *finger* may vary in different species. The cone is usually single, but is bifid in the group *Pseudomyzomyia*. The *mentum* lies in the middle line about the middle of the head ventrally; it carries a single apical and from 3–5 lateral teeth on each side, the arrangement and character of which are important. Ventral to the mentum is the somewhat similar *submentum*, with the apical tooth usually double . . .

" *Thorax*.

" The division of the thorax into pro-, meso- and meta-thorax is only indefinitely indicated externally, but the limits of these parts will be sufficiently clear from the figure (Fig. 10). Towards the front of the thorax on either side are the retractile transparent notched organs of Nuttall and Shipley. The long, branched, lateral hairs, of which the bases only are shown, vary very little in different species and are of little systematic importance. The various hairs of the thorax are shown in the figure; the most important for taxonomic purposes are hairs

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Mesothorax.

1. Large dorsal hair (representing palmate hair).
2–7. Small dorso-lateral hairs.
8. Large lateral hair (No. 9 of Martini).
9–12. Pleural hairs (Nos. 10–13 of Martini and Root).
13. Submedian hair (No. 14 of Martini and Root).
14. Small lateral hair (No. 8 of Martini, No. 9 of Root).

Metathorax.

1. Representing palmate hair (No. 4 of Martini and Root).
2. Small dorso-lateral hair (No. 3 of Martini and Root).
3. Small dorso-lateral hair (No. 2 of Martini and Root).
4. Small dorso-lateral hair (No. 1 of Martini and Root).
5. Large lateral hair.
6. Small hair posterior to 7 and 8.
7–8. Large lateral hairs.
9–12. Pleural hairs.
13. Submedian ventral.

Nos. 1–3 of the prothorax (*submedian prothoracic* or shoulder hairs) and the *pleural* hairs.

"The *submedian prothoracic* (shoulder hairs) comprise an *inner*, *middle*, and *outer* hair on each side. The middle hair is usually much the largest, twice or more the length of the inner; it is stout and feathered and arises from a chitinized tubercle. The inner hair may be feathered or have a few branches only, or sometimes even be simple; it may arise from a thickened base, which may, however, be poorly developed or fused with that of the middle hair. The outer hair is short and simple . . . it arises without a thickened base or from the base of the middle hair.

"Hair No. 1 on the prothorax is the inner shoulder hair. On the mesothorax it is a conspicuous large, stout hair arising from a thickened tubercle towards the middle of the dorsum on each side. On the metathorax it may exist as an ordinary hair, but is commonly formed into a modified or fairly well developed *palmate hair*, the test of which is whether the branches arise together and are flattened; it resembles, but is never so well developed as, the palmate hairs on the abdominal segments II–VII, and the leaflets are without a filament.

"*Pleural Hairs.*

"These form one of the most important characters in Puri's classification of the Anophelini on larval structures. Each segment of the thorax carries on the ventro-lateral surface of each side a group of four *pleural hairs*, arising from a common chitinized base; they cannot be mistaken, owing to the common origin of the hairs from characteristic tubercles which carry a chitinized projection (Fig. 10).

"The four hairs are arranged in each segment as an *anterior* and a *posterior* pair, each composed of a *dorsal* and a *ventral* hair. Of these, the anterior pairs are long, while the posterior pairs are short or vestigial, except on the prothorax, where the ventral hair is also long. There are, therefore, present on the thorax on each side, three pro-, two meso- and two metathoracic *long pleural hairs*. The posterior dorsal on the prothorax may in some cases also be long, giving four longish hairs on the prothorax, but this is never more than one-half or two-thirds the length of the others. The various conditions of these hairs, whether simple or feathered, form combinations that, with a few exceptions, are characteristic of the different genera, subgenera, and groups."

"The group *Myzomyia* of the subgenus Myzomyia has the prothoracic dorsal anterior long pleural hair feathered, likewise the metathoracic dorsal anterior, all the other long pleural hairs on the pro-, meso-, and metathorax are simple.

The Abdomen.

"Abdominal segments I–VII are of simple construction. Segment VIII posteriorly is slightly modified, its posterior tergal plate forming the fan-shaped plate of the spiracular apparatus. Segment IX is much reduced and modified, being represented in parts of the spiracular apparatus. Segment X forms an appendage-like mass (*anal lobe*), which carries the

caudal hairs and four *anal papillæ*, the latter arising round the margins of the anus; it is strictly a composite segment, including elements of segment XI.

"Near the anterior border of each segment is an oval chitinous plate, which may be small or large (*anterior tergal plate*); about the middle of each segment is another very small rounded plate (*posterior tergal plate*). In group *Myzomyia* most species show, also, a little behind the posterior tergal plate, a pair of small, dark, oval plates, lying one on each side of the middle line (*paired oval plates*). The anterior tergal plates are very large in the species *funestus*, *fluviatilis*, *minimus*, and related forms, and may include the paired oval plates.

"The structures about the spiracles are shown in Fig. 9 and Fig. 11. Along the posterior borders of the spiracles is a crescentic chitinization, which may be poorly or well developed (*spiracular chitinization*). When the anterior border of the *median plate* is broad it may approach or touch the spiracular chitinizations. On each side of the *scoop*, or posterior projection of the spiracular parts, is a comb-like structure, *pecten* (or comb),* which carries long and shorter spinous projections, all of which are usually finely serrated on their basal half, only exceptions to this being noted in the descriptions.

"The hairs of the abdominal segments are shown in Fig. 11. The most important hairs are No. 1 (palmate or float hairs) and Nos. 6–7 (lateral hairs).

"On segments I and II *hair No.* 1 may be an ordinary small branched hair or developed as a *palmate hair*; it is considered a palmate hair when the branches arise all together in a whorl and are flattened. On segments III–VII the hair is generally transformed into a well-marked palmate hair with from 12–24 *leaflets*. In subgenus *Myzomyia* the leaflets consist of a basal portion (*blade*) and a terminal *filament*, usually with a number of more or less closely-set serrations at the point of origin of the filament (*shoulder serrations*). In subgenera *Anopheles* and *Nyssorhynchus* the leaflets are usually lanceolate in shape, or the differentiation of the filament is imperfect, the serrations being spread out more or less along the apical portion of the leaflet.

"The *lateral hairs* on segments I and II form two stout, feathered hairs, a dorsal (6) and a ventral (7); in most species the dorsal hair is also present as a stout, feathered hair on segment III (normal arrangement). In some species hair No. 6 on segment III is not stout, has few branches, or is short. On segments IV–V hair No. 6 is very long and somewhat slender, splitting near its base or about its middle into 2–10 branches, approaching in appearance a feathered hair where the number of branches is large. On segment VI it is very long and somewhat slender in *Myzomyia*, some *Nyssorhynchus*" (not Australian—F.H.T.) "and tree-hole breeding *Anopheles*, but short otherwise in this last subgenus; it may be simple or branched and is feathered in *A. annandalei*. On segment VII No. 6 is very short and branched."

"The *postspiracular* hair (hair No. 9 of segment IX) in the great majority of species has 3–8 branches . . . The saddle-hair is practically always long and simple . . .

* The term "pecten" is preferable, as this structure is homologous with the pecten, and not with the comb of culicine larvæ.

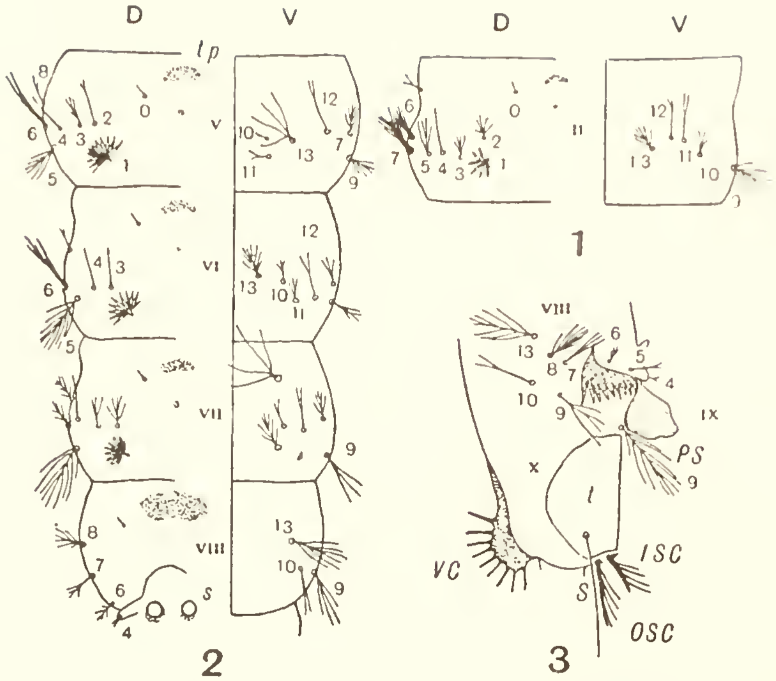

Fig. 11.—Hairs of abdomen of larva (*after* Puri) : 1, abdominal segment II, dorsal (*D*) and ventral view (*V*), showing hairs ; 2, abdominal segments V–VIII, dorsal and ventral view, showing hairs ; 3, lateral view of segments VIII–X, and anal lobe, showing hairs.

Abdominal Segments I–VII.

0. Submedian dorsal.
1. Palmate hair.
2. Prepalmate (posterior to palmate hair on segment VI).
3–4. Small dorso-lateral hairs.
5. Dorso-lateral posterior.
6–7. Lateral hairs.
8. Stigmatic hair.
9. Ventro-lateral posterior.
10–12. Ventro-lateral small hairs.
13. Submedian ventral.

Segment VIII.

0. Submedian dorsal.
1–3. Fossate hairs (not shown in figure).
4. Hair at tip of lateral papilla.
5. Hair at base of lateral papilla.
6. Pecten hair (hair *h* of Martini).
7. Subpecten hair (hair 6 of Martini).
8. Small lateral hair (hair 7 of Martini).
9. Ventro-lateral posterior.
10. Small ventro-lateral hair (hair 11 of Martini).
13. Submedian ventral.

Segment IX.

1–4. Hairs of scoop (hairs *a-d* of Martini) (not shown in figure).
6. Hair on ventral aspect of scoop (hair *e* of Martini) (not shown in figure).
8. Hair on ventral aspect of scoop (hair *f* of Martini) (not shown in figure).
9. Postspiracular hair (hair *g* of Martini) (*PS*).

Segment X.

ISC, Inner submedian caudal (tail-hairs of Martini).
OSC, Outer submedian caudal (dorsal hairs of Root).
S, Lateral hair (saddle-hair).
VC, Ventral caudal (rudder-hairs of Martini, ventral fan of Root).
s, spiracle.
t, tergal plate of anal lobe.
tp, tergal plates of abdominal segments.

"Arising from chitinized plates above the anus are the *inner* and *outer submedian caudal hairs*. The ends of the branches of the latter are usually curved to form hooks (*tail-hooks*); some branches of the inner may in some species also form delicate hooks. Ventral to the anus are the rudder-like *ventral caudal hairs*.

"*Characters of the Egg.*

"With rare exceptions the egg of the Anophelini is boat-shaped, with pointed ends, a flattish deck or upper surface, and a more convex lower surface; the end of the egg corresponding to the head of the larva is somewhat broader and blunter than the other. Surrounding the whole, or parts, of the upper surface is the frill; at the sides of the egg are the floats.

"The *upper surface** is usually unornamented, but may show small, pale, punctate spots over the whole or portions of its extent and rarely may show polygonal markings. In those species in which the frill does not entirely surround the upper surface it usually marks off a portion at either end (*anterior* and *posterior demarcated areas*), somewhat horseshoe-shaped, whilst the *median area*, bordered by the floats, is roughly quadrangular in outline. At both extremities at the extreme points are a number of small, usually black, tubercles (*bosses*).

"The *lower surface* in subgenus *Anopheles* is usually ornamented with a pale polygonal network; in subgenus *Myzomyia* it is granular or may show pale punctæ. At the anterior extremity of the lower surface, just below the point of the egg, is the *micropilar area*. This is usually seen as a small, dark, papular area with a central depression, the *micropile*; it may show a delicate, pale, scalloped line surrounding it.

"The *frill* may be broad or narrow; it is usually striated in the whole or part of its extent. Where it is not continued past the floats it may end by merging gradually into these or terminate more abruptly, in which case it usually ends in a small projecting *tag*.

"The *floats* show a number of corrugations (*float-ridges*), and at either end there is commonly a more or less distinct terminal cell (*float-termination*), which may be large and rounded or small, and giving the float a pointed extremity."

For minute structure and development of the egg from the follicle, see Christophers and Nicholson. The orientation of the egg and contained larva is dealt with by Bresslau. The flat side (upper surface) corresponds to the flatter side of the *Culex* egg and is *ventral*. The convexity (lower surface) is dorsal. The larva lies with the head towards the large end of the egg, with its ventral surface corresponding to the flat upper surface. The egg-breaker lies opposite the convexity of the egg towards the anterior end. The caudal hairs are directed forwards along the sides of the egg, and the balancer-hairs forwards and upwards towards the anterior end of the egg.

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* As the upper surface corresponds to the ventral aspect of the contained larva, it is better to term this the upper surface rather than the dorsal surface, as given in Christophers and Barraud, 1931.

BIONOMICS AND RELATION TO DISEASE.

Metamorphosis and Early Stages.

"The eggs are laid either singly and directly upon water, or heaped up on the bank or some floating object. When first laid, the eggs are white, but they darken rapidly, and in a few hours become a deep black. Premature or unfertilized eggs may remain white and do not hatch. When laid directly on water, or when the heaped-up eggs are placed on water, they form patterns, due to the action of surface tension and the shape of the egg. Where the egg is broad and oval, with prominent floats, they tend to come together in sets of three eggs, with their poles approximated, forming triangles or larger groups of stars or six-rayed hexagons. Where the egg is longer and straighter, or where it has a very broad frill or lacks floats, many, or all, the eggs become arranged side by side, forming straight or curved ribbon-like groups. When floating free the eggs tend to accumulate at the edge of the vessel or bank, and are drawn up on the meniscus with the narrow end upwards and the broader end, due to its greater weight, downwards.

"Hatching under normal conditions in the tropics usually occurs in about 48 hours, but may be delayed. Eggs up to about 12 hours after deposition are susceptible to desiccation, and do not hatch if dried and later placed on water. After development has proceeded for 24 hours or more, even though they are wrinkled, eggs hatch, usually after some delay, when placed on water, if the period of desiccation has not exceeded about 48 hours. Eggs kept moist but not on water do not hatch, but remain viable for periods up to 10–16 days, and hatch almost at once on being placed on water. Cold delays hatching, and below certain temperatures (about 60° F. in some species) the eggs do not hatch unless the temperature is raised. Eggs may be kept at low temperatures (in ice), in some cases for long periods, without affecting their ultimate hatching.

"The larva escapes by a spiral cut or break, forming a cap at the thick end of the egg, probably produced by the action of the egg-breaker and rotation of the head. The break is mainly on the lower surface, and the cap is left attached mainly by a portion of the deck. Larvæ, when hatched on wet blotting-paper or a floating leaf, etc., crawl, especially downwards, to reach the water.

"The whole period of metamorphosis from oviposition to emergence of the adult usually lasts under favourable conditions in the tropics from about 13–19 days, but may be as short as 9–10 days in exceptional cases, or longer, with certain species, under unfavourable conditions or low temperature. The larval period may, under favourable conditions, be 8–9 days, or extended to a month or more under low temperatures or unfavourable conditions in regard to food. In species breeding in tree-holes the time may be very variable; Hacker records larvæ of *A. asiaticus* as living up to 163 days without pupating, though eventually emerging as adults. The first three instars last about two days each, the last instar being about twice as long.

"The larva usually lies at rest at the surface, with the caudal end against some object, and the body directed at right angles

to this, the position being largely maintained by physical forces. When disturbed, the larva either swims backwards in a series of wriggling, zigzag, or scuttling movements of the body, allows itself to sink, or swims rapidly downwards, tail first, to the bottom or to a considerable depth if in deep water. Young larvæ are usually less readily alarmed than older larvæ, which may be extremely alert, and sink, even as the result of tremors of approaching footsteps in some cases. Larvæ when disturbed may remain inert, and apparently dead, at the bottom, or hanging by their tail-hooks to the sides of a tank or vegetation up to 20 minutes or more, but usually they return after a minute or so to the surface and immediately swim to shelter. In running water they may attach themselves by their caudal tail-hooks to maintain their position. They may sometimes remain beneath the surface attached to confervæ on stones or to vegetation, apparently respiring in this position.

"Feeding takes place usually whenever at rest and undisturbed at the surface. The head is rotated to bring the ventral surface uppermost, and contact is made with the surface film by the maxillæ and submentum. The brushes are then worked rapidly and rhythmically, setting up a shallow surface current under the surface film directed to the head of the larva from in front. The current impinges against the closed mandibles and is shot out from the outer surface at right angles on each side of the head. As the current passes through the mouth it is combed by the maxillæ, which are in constant vibratile movement. After accumulation of a certain amount of solid matter in the mouth this is passed in a bolus into the œsophagus. Particles as small as bacteria are removed from the stream.

"The food of larvæ is of a miscellaneous character, consisting of formed and unformed organic matter. With this is usually included a considerable amount of small spicules of silica and particles of other mineral matter. The formed material consists of unicellular algæ, flagellates, ciliates, and other floating vegetable and animal life. The nature of the brown amorphous unformed material that forms a considerable proportion of the food is not known. Larvæ may be reared on pure cultures of *Euglena*, yeast, etc. Where the water is especially shallow larvæ of some species may browse at the bottom on organic particulate matter.

"Change into the pupal stage occurs suddenly in full-grown larvæ after a short period, during which these cease to feed and rest at the surface, usually hanging down a little from the surface film in the attitude of an *A. turkhudi* larva. The pupal stage usually lasts in the tropics for 36–48 hours. Lamborn has never observed prolongation of this stage as of the larval period. At low temperatures, and especially with large species, the period may be longer (8 days in *A. gigas* in cool weather in the hills). The pupa, more frequently than the larva, may remain anchored to stones, etc., beneath the surface; they also tend to secrete themselves amongst vegetation and under rocky ledges, etc.

"Emergence of the adult usually occurs in the tropics in the evening or at night before 11 p.m., but in cold climates emergence is usually at some time during the day. The pro-

portion of the two sexes emerging is always about equal, with a slight preponderance of females. Sex has been supposed to depend to some extent on the food-supply of the larva, but this is almost certainly not so, as the sex is already detectable in very young larvæ.

" *Breeding Places.*

" The sites where larvæ are found breeding in nature are known as breeding places. The nature of the water forming breeding places is of a very varied character, but the collections are either small in extent, e.g. pools, puddles, tree-holes, or have shelter provided by vegetation, e.g. swamps, river-margins, rice-fields, etc. Only few species are sometimes found in foul or much polluted water." So far as is known no Australian species breeds in such places (F.H.T.).

" Different species may show predilection for certain types of breeding place (*selective breeding*). This predilection is not always according to the actual type of breeding place, but depends upon some requirement that may be present in several types. To ascertain what the actual requirements are, the physico-chemical characters of the water of breeding places have been much studied. With the same object the extent to which different species are found breeding together has been investigated (*association*). Similarly there exist many œcological studies of breeding places dealing with favourable and unfavourable vegetation, etc.

" Selective breeding and association do not appear to be directly related in any degree to the physico-chemical characters such as hydrogen-ion concentration, dissolved oxygen, albuminoid nitrogen and absorbed oxygen, etc., though they may show an indirect relationship. Gater and Rajahmoney have analyzed breeding places in the Federated Malay States under the categories of swamps, ponds, rice-fields, streams, drains, seepages, wells, pools, sumps, artificial containers, hoof-marks, cut and bored bamboos, and miscellaneous. A better classification to bring out selective breeding habits of species would be one where such categories are subordinated to general œcological conditions and, in particular, one taking note of the surroundings. To classify breeding places logically is, however, very difficult, and no really satisfactory classification or method of setting these out has yet been given . . .

" *Habits and Behaviour of the Adult.*

" Adults of many species are to be found in cattle-sheds and unoccupied disused rooms, where they are to be captured, often in large numbers, resting on the cobwebs, on and among thatch where it is dirty and sooty, among dung-cakes, in grain receptacles resting on chaff, sheltered behind stored agricultural implements, and such-like situations. They are usually less numerous in occupied rooms, as the type of shelter is less suitable, and they are liable to be driven out in the early morning by smoke.

" Males are not attracted, when seeking shelter, to the same extent as the females, by the presence of man or animals, and tend to shelter elsewhere ; they are also liable to die off more rapidly, at least in the drier climates. Probably, for these

reasons, catches of adults in houses and cow-sheds usually show a great preponderance of females.

"Such species as are found resting in houses and cattle-sheds, and very often breeding not very far from habitations, are frequently referred to as 'domestic' species; those found almost entirely in forest or jungle, which attack man (when they do so) only in their own native haunts, are commonly called 'wild' species. Some species are intermediate in character and enter houses to feed, but leave before the morning, and shelter during the day in the jungle or undergrowth.

"A large proportion of the species in the tribe have been observed to feed on human or animal blood in nature or experimentally, or to have been caught engorged with blood . . . Even wild species frequently attempt to feed in the shade of the forest or near their breeding places. Domestic species usually feed by night or at dusk, but may do so, especially in warm weather, during the day.

"Certain species are more especially associated with cattle; others show a relatively greater tendency to be found in houses (*house-frequenting species*). The term *zoophilism* has been given to a condition much studied in Europe, where different races of *A. maculipennis* are recognized, some showing a marked preference for cattle-blood as against human blood. This was at one time believed to be the result of selective breeding, where large numbers of cattle are permanently stabled under certain conditions, but is now recognized as due to the occurrence of varieties of *A. maculipennis* differing in regard to their associative habits with man and cattle respectively. Protection may be brought about through the presence of cattle, which attract *Anopheles* and reduce the number feeding on man (*deviation of Anopheles*)."

Whether cattle protect, or to what extent they may do so, is not known in Australia. *Anopheles annulipes* certainly does feed on horses and cattle but should a person be near by it will attack him with equal avidity. This has been observed by me.

"*Anopheles* do not remain every night in the shed or room in which they have rested during the day, but appear almost nightly to change their resting place, so that the anopheline population of any particular room or shed is perpetually changing, and infected *Anopheles* are as likely to be found in a cow-shed as in a human dwelling (*nightly turnover*).

"The distance traversed by Anophelini from their breeding places in search of food may be considerable, but usually does not exceed about a quarter of a mile. In open country distances of several kilometres have been recorded as traversed under some circumstances. There appear to be authentic instances where *Anopheles* have appeared on ships at a distance of some miles from shore. Some species appear to be stronger fliers than others. Besides active dispersal in this way, Anophelini are frequently carried considerable distances by trains, steamers or vehicles (*passive dispersal* or *conveyance*).

"In captivity in the tropics Anophelini do not appear to mate very readily, but fertilization occurs usually if freshly hatched males and females are left together and the latter allowed a blood meal; better results, according to MacGregor, are

obtained if suitable food (raisins or glucose solution) be given also to the males. Fertilization of the female appears to occur in nature under Indian conditions on the first or second night after emergence, as all females caught in houses or sheds, except those evidently newly hatched, show spermatozoa in the spermatheca. Swarming of males has been described in Europe, West Africa, Egypt, and the Philippines ('*rossii*'), but not, so far, in the Indian area, though it probably occurs. Fertilization probably occurs, apart from swarming in the open, in houses or sheds.

"In the case of domestic species in the tropics, blood is taken very early—as a rule by the second night at least—and the ovaries begin a rapid development, which may be completed in some five days. An even shorter time is required for subsequent batches of eggs owing to the second follicle undergoing preparatory development before the eggs of the previous follicle are laid.

"When the ovaries are approaching maturation the female ceases to feed and digests all the blood in the gut. On reaching this stage they leave the village to seek suitable places for oviposition. Following successful oviposition, they may return again to the same or some other source of blood-supply. Oviposition under artificial conditions usually occurs some time during the night. The female fixes the anterior legs upon the sides of the vessel or other support and lowers the body, with the wings folded, horizontally towards the water, all the tarsi being flat on the water. Each egg is extruded abruptly upwards from the extremity of the abdomen. After remaining some seconds in this position the egg falls and another egg is extruded: eggs are laid at a rate of about 6–10 per minute. Somewhat less than 100 are commonly laid, but the number may exceed 100 or, in some species, may amount to several hundreds."

SYSTEMATIC DESCRIPTIONS.

Subfamily Culicinæ.

Characters.—Mouth-parts elongate, formed for biting. Mandibles nearly always present in ♀, sometimes toothed apically, as is the blade of the maxilla. Maxillary palpi seldom longer than labium (never in ♀), not incurved, but usually porrect; seldom with four distinct segments. Labium always many times longer than clypeus, which is always shorter than the head and almost always bare. Antennæ with the first scapal segment reduced to a narrow ring, second much enlarged, especially in ♂; flagellum always with 13 segments, usually plumose in ♂, but sometimes alike in the two sexes, all segments except first with basal hair-whorls. Head clothed with scales, some at least of those on the nape being erect and forked, those on the vertex variable in form, those on the sides broad and flat. Eyes uniform, often contiguous above antennæ. Thorax with dorsal vestiture consisting of bristly hairs and scales of various shapes; pleuræ usually with more or less extensive patches of flat scales. Posterior pronotum usually with hairs near posterior margin. Sternopleurite not separated from anepisternite by a distinct suture (except perhaps in some species of *Uranotænia*). Meron (Figs. 4, 29) forming a conspicuous triangular sclerite

completely separating the middle coxa from the mesepimeron. Mesosternum ridged. Abdomen usually bearing scales (except in Anophelini). Spiracles present on segments 2–7. Hypopygium always inverted through 180° after emergence from pupa; ninth segment usually much reduced, anal segment usually with some chitinizations; aedeagus varied in structure but usually complicated. Legs always covered with scales, which are usually flat and close-lying. Wings with the fringe of the posterior margin composed of scales in three rows, those of the first row small and oblique, the others longer. Veins clothed with hairs or scales of various shapes. *Sc* always reaching far beyond base of *Rs*; R_{2+3} never arched, but in line with *Rs*.

Pupa (Figs. 8, 31).—Respiratory trumpet variously developed, but always open at tip, the actual spiracle at or close to its base, surface never with hexagonal reticulation as in Chaoborinæ. First abdominal segment usually with a pair of large hair-tufts which serve for attachment to the surface film. Eighth segment almost or quite as large as seventh, with a pair of large, flat, movable and completely separate paddles; paddles provided with a strong midrib and also thickened on the outer but not on the inner margin. The pupa swims much more actively than in the Dixinæ and Chaoborinæ, and always rests with the cephalothorax horizontal and the abdomen curved under the thorax, not hanging vertically.

Larva (Figs. 9, 33).—Varies in form and habits, but posterior spiracles always functional, prothoracic spiracles never so (two pairs of thoracic and seven pairs of lateral abdominal spiracles are sometimes distinguishable, e.g. in the larva of *Opifex*, but are closed). Many larvæ are predaceous but in none of these are the antennæ modified for capturing the prey, some other organ (mouth-brushes, maxillæ or mandibles) being used instead. The fore-gut is always continuous with the mid and hind gut, never eversible as in Chaoborinæ. Mouth-brushes well developed from lateral lobes of labrum. Thoracic segments all more or less completely fused, always wider than abdomen. No ventral pseudopods, and no eversible groups of hooks on ninth abdominal segment. Anal gills (as in the other subfamilies) nearly always four in number and never retractile.

Classification.—The subfamily Culicinæ is here regarded as including all the true mosquitoes, and is co-extensive with the family Culicidæ as understood by Theobald and some other writers. Various systems of classification have been proposed from time to time, which it is unnecessary to review here; Theobald admitted as many as eight subfamilies, but at present we recognize only three tribes, distinguishable as follows:

Key to Tribes.

Adults.

1. Abdomen without scales, or at least with the sternites largely bare — Tribe Anophelini
   Abdomen with both tergites and sternites completely clothed with scales 2
2. Proboscis rigid, outer half more slender and bent backwards — Tribe Megarhinini
   Proboscis more flexible, of uniform thickness (unless swollen at tip), outer half not bent backwards .. .. .. Tribe Culicini

Pupæ.

1. Lateral apical hairs of abdominal segments placed almost exactly at corners .. .. Tribe Anophelini
   Lateral hairs of abdominal segments placed well before apical corners .. 2
2. Outer portion of paddle produced beyond tip of midrib .. .. Tribe Megarhinini
   Outer portion of paddle not longer than midrib .. Tribe Culicini

Larvæ.

1. Spiracles sessile, siphon absent .. .. .. Tribe Anophelini
   Spiracles at tip of a siphon-tube, which is at least as long as broad .. 2
2. Mouth-brushes prehensile, each composed of ten stout rods .. .. Tribe Megarhinini
   Mouth-brushes rarely prehensile, composed of 30 or more hairs .. Tribe Culicini

Tribe Anophelini.

Characters.—Adult: Clypeus somewhat longer than broad, rounded in front. Dorsal surface of head with the upright scales usually packed, but the close-lying scales very few or absent; usually a few long, narrow, more or less hair-like scales projecting forward over junction of eyes. Labium slender and flexible throughout. Mandibles and maxillæ of ♀ well developed and toothed. Palpi in both sexes usually about as long as proboscis, but shortened in ♀ of several species. Thorax usually very little arched; scutellum evenly rounded (except in *Chagasia*). Abdomen either without scales, or with a variable development of loosely applied scales; in the most scaly species the sternites at least are largely bare. Hypopygium of ♂ (Fig. 6) with long slender unmodified styles bearing a short terminal spine; coxites short and usually without distinct basal lobes; anal segment either entirely membranous or with feebly developed simple paraprocts; ædeagus (Fig. 6) tubular, with or without one or more pairs of reflexed "leaflets" (Fig. 6) at its tip. Female with only one spermatheca. Legs very long and slender, uniformly covered with small flat close-lying scales; no distinct tibial bristles; no pulvilli. Wings (Fig. 5) usually with distinct markings. Basal section of R_{4+5} vertical, cross-vein-like; *r-m* cross-vein either in line with base of R_{4+5} or with a right-angled bend, the vertical portion being before base of *Rs*; a scale-bearing spur (Fig. 5) is nearly always present extending towards base of wing from angle of R_{4+5}. Squamæ always with fringe (Fig. 13).

Pupa.—Respiratory trumpet always short and widely open. Abdomen with similar longish or spine-like hairs placed at or close to posterior lateral corners of each of segments 3–7; segment 8 with a stout, strongly plumose hair at corner. Paddles with a hair at tip of midrib, and a smaller one on midrib some distance from tip (Fig. 8).

Larva (Fig. 9).—All the larger hairs of the body tending to be pinnately branched (i.e. with a series of moderately long branches arranged along each side); very rarely are any of the hairs (apart from the float-hairs) branched in a fan-like manner (from the base). Head usually somewhat longer than broad, and freely rotatable, so that the ventral surface may be uppermost in feeding. Dorsal surface with three pairs of hairs near front, two close to front margin (inner and outer anterior

clypeal) and one further back (posterior clypeal); a row of pinnate frontal hairs across middle (usually six in number, but only four in *Chagasia*); four smaller hairs posteriorly. A large pinnate hair (subantennal) immediately below root of antenna. Antenna of moderate length, with one hair (simple or branched, rarely absent) and nearly always with small spinules on shaft; two small and two rather stout apical spines, between which is a hair (often branched). Mouth-brushes composed of a large number of simple hairs. Mentum rather long and narrow and irregularly toothed. Thorax always much broader than head. On front margin of prothorax towards each side is a transparent, fleshy, slightly forked, eversible appendage, which serves for attachment of the front part of the body to the surface film. Three long and strong pinnate hairs dorso-laterally on pro- and metathorax, their bases set in very small plates; lateral hairs of mesothorax smaller and usually simple. On front margin of prothorax, towards middle line is a group of three hairs ("shoulder hairs"), two of which are of moderate size and usually pinnate, the third always small and simple. Prothoracic pleural group with three long hairs and one short; mesothoracic with two long and two short; metathoracic also with two long and two short (except in *Chagasia*, which has three long and one short); meso- and metathoracic pleural groups accompanied by a strong spine arising from a small plate. Abdomen with a series of "float-hairs", occurring in pairs on some or all of the first seven abdominal segments (most often on segments 3–7, as in figure); each float-hair consisting typically of a short, stout erect basal piece and about 12–20 flattened "leaflets" which are spread out in one plane like a widely-open fan. Segments 1 and 2 each with two long pinnate lateral hairs (balancer hairs), one above the other; segment 3 usually with one such hair; lateral hairs of remaining segments usually shorter. Between each segment dorsally is a chitinous plate, small or large. Eighth segment postero-dorsally with a lateral chitinous plate bearing posteriorly a row of strong teeth (pecten); towards base of plate is a small branched hair; the plates of each side are connected with one another posteriorly by a very narrow band of chitin which passes dorsally immediately behind the respiratory apparatus, but is not continuous in front of the latter to form an air-tube. No lateral "comb" on eighth segment after the first stage. Respiratory apparatus consisting of four plates: a median one in front of spiracles; a small lateral plate on each side of spiracles, and a large posterior plate (or pair of fused plates) with three anterior processes and a posterior median emargination. Anal segment with the four postero-dorsal hairs and the hairs of the large ventral brush rather thickly and irregularly branched.

Genus *Anopheles* Meigen.

Anopheles Meigen, *Syst. Beschr.*, I, 1818, 10.

Characters.—Adult (Fig. 12): Head with the neck projecting directly forwards and supported by long lateral cervical plates. Antennæ of ♂ plumose; of ♀ with whorls of hairs at bases of segments, the hairs evenly spread all round. Palpi normally about as long as proboscis in both sexes, rarely somewhat shorter, never much less than three-quarters as long as

Fig. 12.—Side view of female *Anopheles* (*Myzomyia*) *kochi* Dön. to show Anopheline characteristics. *After* Edwards.

proboscis, even in ♀. Palpi of ♂ with the last two segments rather conspicuously swollen (somewhat flattened in section), usually turned outwards in repose. Thorax always distinctly longer than broad, not much arched dorsally. Anterior pronotal lobes more or less prominent in front. Posterior pronotal lobes quite bare, without hairs or scales. Scutellum evenly rounded, with a regular row of bristles on posterior margin. Middle part of sternopleura without bristles, those of the upper and lower series short. Hypopygium without basal lobe on coxite, but with from one to five spines or stout bristles in this position. Legs variously ornamented or unmarked, rarely with white bands at bases of tarsal segments. Fifth tarsal segment of front legs of ♂ longer than or subequal to fourth, with a bristly swelling at base and bearing only one claw which has basal and median teeth. Fifth tarsal segment of middle legs in both sexes somewhat longer than fourth, without bristly swelling at base, and bearing two rather small, equal and simple claws. Wings (Fig. 13) with or without markings. Upper fork never much shorter than its stem (sometimes longer). Stem of lower (median) fork always straight ; terminal section of Cu_1 rarely slightly concave above. All veins rather densely scaly, including *An*.

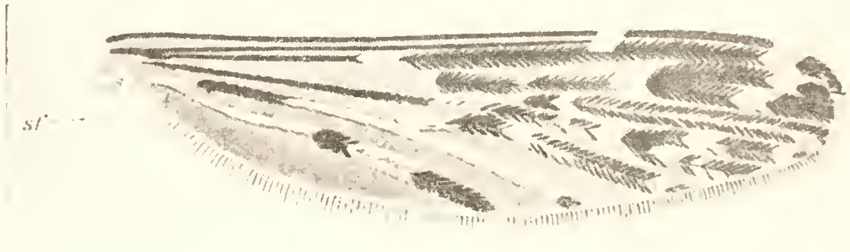


Fig. 13.—*Anopheles* wing showing squamal fringe. *After* Edwards.

Larva (Fig. 9).—Head without spines near front margin of clypeus. Clypeal hairs variously formed, but the three pairs usually dissimilar and never with a fan-like tuft at the end of a long stalk. A transverse row of six pinnate frontal hairs. Apical hair of antenna (between spines) with few branches, usually from near base, or at most slightly pinnate. Thorax with the middle hair of the anterior submedian group simply pinnate. Pleural hairs various, but only two long ones on metathorax. Abdomen with a long feathered lateral hair on segment 3, rarely also on segments 4–7. Anterior median flap

of spiracular apparatus somewhat triangular, without apical filament; posterior pair of flaps without lateral hairs. Float-hairs normally present on segments 3–7, their component filaments usually elliptical, with or without "shoulder", but never racquet-shaped. Dorsal hairs of anal segment and hairs of ventral brush irregularly pinnate. Skin of thorax and abdomen rarely pubescent.

Eggs.—Very varied in form in the different species, usually with lateral or dorsal "floats" formed by a corrugated membrane.

Keys to Subgenera.

Adults.

1. Thorax blackish, with a broad grey line from neck to scutellum .. Subgenus *Stethomyia* Theobald
   Thoracic ornamentation quite otherwise 2
2. Wings rarely with more than two pale spots on costa; ♂ coxite with 1–3 (usually 2) strong basal spines set on tubercles .. .. Subgenus *Anopheles* Meigen
   Wings usually with 4 or more pale costal spots 3
3. New world; ♂ coxite with one spine at base and two more beyond .. .. .. Subgenus *Nyssorhynchus* Blanchard
   Old world; ♂ coxite with several rather weak spines near base, not set on tubercles .. .. Subgenus *Myzomyia* Blanchard

Larvæ.

1. Anterior lobes of spiracular apparatus each with a long finger-like process; spiracles prominent and wide apart .. .. .. Subgenus *Stethomyia* Theobald
   Anterior lobes of spiracular apparatus with short process or none; spiracles sessile and closer together 2
2. Antenna with branched hair on shaft (except in some tree-hole species) .. .. .. Subgenus *Anopheles* Meigen
   Subgenus *Nyssorhynchus* Blanchard
   Antenna with simple hair on shaft Subgenus *Myzomyia* Blanchard

Subgenus *Anopheles* Meigen, S. Str.

Syst. Beschr., 1, 1818, 10. Type *maculipennis* Mg.

"*Characters.*—Adult: Propleural hairs usually numerous (only one in *A. aitkeni*). Spiracular hair usually present and rather long, rarely few and short or even absent (*A. marteri*). Pre-alar hairs present. Female without buccopharyngeal armature. Hypopygium with from one to three (usually two) spines at base of coxite, set on distinctly raised tubercles or a slight lobe, another slender spine on inner margin of coxite near or beyond middle. Wings (Fig. 14) usually dark; if with pale markings, the bases of fork-cells and areas of veins immediately adjacent to cross-veins almost always remain dark.

"*Pupa.*—Lateral apical hairs of abdominal segments usually short and rather blunt-tipped; terminal hair of paddle (Fig. 8) rather short and usually straight; hairs C (admedian hairs on posterior margin) of segments 5–7 shorter than the segments and usually branched.

"*Larva.*—Hair on shaft of antenna always branched, even if small, and usually on inner surface. Inner anterior clypeal hairs set close together, their distance apart at most equal to one-sixth of their length (hairs well separated in *A. pseudopunctipennis*). The longer hairs (three prothoracic, two mesothoracic and two metathoracic) in the pleural groups are all simple (one of the prothoracic hairs slightly branched in

A. aitkeni). Leaflets of float-hairs usually elliptical, without distinct shoulder (shoulder and filament present in *A. aitkeni* and a few other species). Lateral flaps of spiracular apparatus (Fig. 9) without long tentacular appendages. Segment 6 of abdomen usually without long lateral hairs.

"*Classification and Distribution.*—Following Christophers, we may recognize three main groups of the subgenus:

"Group A (*Anopheles*). Abdomen without scales dorsally or laterally, except sometimes on last segment. The species of this group fall into several series, between which it is difficult to draw sharp lines of distinction. The following four are recognized in the arrangement below:

"(*a*) The *Anopheles* series, with the front femora slender or only indistinctly swollen at the base, and the scales of the female palpi appressed or only slightly roughened towards the base. This includes all the species of *Anopheles* with completely dark wings and legs and also some (*punctipennis*, *pseudopunctipennis*, *gigas*) with conspicuous wing-markings, or with a broad white ring on the hind femur (*lindesayi*, *wellingtonianus*), or a broad white band at the tip of the hind tibia (*eiseni*, *gilesi*). The group is mainly holarctic in distribution, but it includes also a number of Oriental, Australasian and neotropical species.

"(*b*) The *Myzorhynchus* series, with front femora markedly swollen at the base, and female palpi shaggily scaled to the tips; wings usually with two small pale spots on costa; seventh abdominal segment of female very often with a ventral scale-tuft. Ethiopian and Oriental, two species extending into the Mediterranean region and one into Australia" (Edwards, 1932).

Anopheles bancrofti Giles.

Handbook Gnats, 2nd Ed., 1902, 511; Taylor, Check List Culicidæ of the Australian Region, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 9.

♀.—Head (Fig. 14): Black, clothed with brown narrow curved and upright forked scales, a few upright forked ones in front with pale hairs overhanging the eyes from the centre; palpi densely clothed with black scales, scarcely as long as the proboscis, those of ♂ about as long as proboscis, black shaggy toward base, the latter black with the basal half densely black scaled; eyes deep blue black; antennæ blackish brown, clothed with short white pile, basal lobe with a few flat pale scales at its apex, second segment about twice the length of the third, light brown at the base, densely clothed with brown scales, third short and pale at the apex; plumes of ♂ black.

Thorax dark brown to black, covered with rather long dense pale golden hairs, anterior margin with pale narrow curved scales in the centre with broad brown upright ones on the edges above the prothoracic lobes, the latter brown and prominent, clothed with pale golden hairs and broad upright brown scales on their inner edges; scutellum with the sides creamy yellow, with pale yellowish hair-like scales, centre black, nude, fringed with pale brown hairs; metanotum brown; pleuræ mottled black and brown, with a few scattered white scales.

Fig. 14.—*Anopheles bancrofti* Giles. ♀ head, top left; bottom left, wing. Right, ♂ head.
[From *Aust. Mus. Mag.*

Wing.—Densely covered with black scales for the most part. Creamy coloured spot at junction of subcosta with costa. Five small creamy-white spots on 1 terminating about the distance between spots 4 and 5 from the costal spot; fringe spot at apex of 1; a pale apical spot involving the fringe on 2.1, also a sub-basal one on 2.2, middle and apex black, area between mottled; base of 3 black, rest mottled; fringe spot at apex of 4.1 and 4.2 both mottled; basal two-thirds of 5.2 creamy-white, a small sub-basal and apical black spot on 5.1, remainder mottled, a light fringe spot on 5.1 and 5.2, 5 with a distinct basal spot, then a small creamy one, rest mottled; basal half of 6 mottled, then a distinct black spot, apex with a black spot, intervening area creamy-white.

Abdomen black clothed with golden brown hairs; venter brown, black towards the apex, clothed with flat white scales and brown hairs, the apical half of the seventh segment tufted with dark scales.

♂.—Terminalia: Leaflets, about six in number, very small and short, the longest about half as long as phallosome, remainder much shorter. Basal spines of coxite on a large prominence, each with a well marked tubercle at its base, spines about equal in length, stout, apex narrowed and curved. Club very slender, somewhat like a blunt edged spine. Harpago appears split.

Legs: Coxæ and trochanters brown with patches of white scales; fore, mid and hind femora pale beneath, brown scaled above, with the pale ground colour showing through, the fore femora with the basal half club-shaped; tibiæ dark brown, with the apex dilated and with a white spot, a fairly dense line of white scales above; first tarsi black with creamy white

apical banding, second tarsi brown with creamy apical banding, remaining tarsi brown; second tarsi of mid legs black with a white apical spot, third and fourth black, fifth brown; the second to fourth tarsi of hind legs black with creamy white apical banding, the fourth with basal banding also fifth tarsi; first tarsi of hind legs slightly longer than the tibiæ.

Larva.—Inner clypeal bristles closely approximated, about twice as long as the outer clypeal bristles, abraded, outer clypeal bristles much branched, main stem divided, close to base, into two branches which again are multibranched, the branches carry many tufts of hair. Antennæ covered with many short spines, basal fourth slightly swollen, antennal plume submedian, composed of a stout stem with about seventeen branches, sabres weakly chitinized, terminal hair finely plumed, medio-frontal bristles situated slightly anterior to base of antennæ, plumes fairly long, outer forked twice at apex, with thirty-two plumes; middle with seventeen plumes with a long apical shaft; inner bifurcated at apex, with sixteen plumes, the two apical shafts very long and extending beyond the clypeus. Palmate hairs on segments three to seven each with twenty-two leaflets, latter blackish-brown, filaments pale, serrations at point of origin of filament about three on either side. Pecten with about ten teeth, eight about the same length.

Distribution.—Northern Australia. This species was abundant in Sherwood, a suburb of Brisbane, in 1913; it is still fairly common in the outlying districts of Brisbane. It has never been taken in northern New South Wales, possibly because it has not been searched for. Papua and Territory of New Guinea.

Bionomics.—The larvæ of this species are found in shaded pools, along the grass grown banks of slowly running creeks and rivers, also in pot-holes in creeks and rivers. In fact this species, like *A. amictus*, *A. annulipes*, *A. punctulatus* and *A. punctulatus* var. *moluccensis*, breeds in any clear or muddy ground water. I have not found any of the above species breeding in polluted water.

A. bancrofti will, like the abovenamed species, feed at any hour of the day, in the shade or when the sun is obscured. It also feeds at night time. I have found engorged specimens of *A. bancrofti* in tents during the day, morning and afternoon, when the front and back flaps of the tents have been fastened back, allowing a strong breeze to pass through. *A. amictus* and *A. punctulatus* var. *moluccensis* were taken at the same time in the above tents.

Relation to Disease.—Overbeck and Stoker (1938) state that De Rook found a natural infection index at Tanah Merah in Netherlands New Guinea of 4·3 per cent. The type of malaria found is not stated. No information is available in regard to the ability of this mosquito to transmit malaria in Australia.

Swellengrebel and Rodenwaldt (1932) consider *A. bancrofti* "a very dangerous malaria carrier, contrary to *A. barbirostris*. Walch (1932) ascertained that this . . . is feeding only on human blood."

There is considerable literature from authors in the Netherlands East Indies which points to this mosquito being an efficient intermediary host of *Wuchereria bancrofti* in Netherlands New Guinea.

Subgenus *Myzomyia* Blanchard.

C.R. Soc. Biol., LIV, 1902, 795. Type *rossi* Giles.

"*Characters.*—Adult : Propleural and spiracular hairs variable, often reduced in number or absent. Buccopharyngeal armature of ♀ always present but of various types. Hypopygium with a group of 1–6 spines at base of coxite ; these spines usually more slender than in *Anopheles* s.str., and not set on tubercles or lobe ; no additional spine on inner margin of coxite near middle. Wings (Fig. 5) nearly always with distinct pale markings, including a series of four spots along costa ; bases of fork-cells and areas adjacent to cross-veins almost always with pale scales.

"*Pupa.*—Lateral apical hairs of abdominal segments usually longer than in subgenus *Anopheles* and sharply pointed ; terminal hair of paddle usually long and hooked ; hair *C* (admedian hairs of posterior margin) of segments 5–7 usually as long as the following segment or longer, simple or bifurcate.

"*Larva.*—Hair on shaft of antennae always short and simple, and usually on outer surface. Inner anterior clypeal hairs well separated, their distance apart at least equal to one-fourth of their length. Pleural hairs variable, one or both of the long hairs of the meso- and metathoracic groups often plumose. Leaflets of float-hairs usually with jagged edges and ending in a filament (occasionally elliptical, without shoulder or filament, as in subgenus *Anopheles*). Spiracular apparatus as in subgenus *Anopheles*.

"*Classification and Distribution.*—The rather numerous genera based on details of scale-ornamentation cannot be maintained, but recent researches have shown that there are a number of natural divisions of the subgenus which can be defined on more fundamental characters of both adults and larvae. It would seem from a close study of all the characters that superficial similarity may not indicate relationship, and that a similar type of ornamentation (e.g. markings of hind tarsi or lateral abdominal scale-tufts) may have been developed independently not only in different subgenera of *Anopheles* but even in different groups of the subgenus *Myzomyia*. The most important characters of taxonomic value are those discovered by Barraud, Covell and Sinton (*Ind. J. Med. Res.*, Vol. 15, p. 301–308 and 671–679, 1927–1928) in the buccopharyngeal armature of the ♀ and by Puri (*Ind. J. Med. Res.*, Vol. 16, p. 519–528, 1928) in the pleural hairs of the larvae. These writers recognize three or four main divisions of the subgenus, but it may perhaps be better to recognize six groups, some of which are clearly defined in the larval stage, others in the adult. The arrangement suggested below differs slightly from those hitherto adopted, and is an attempt to combine the work of the authors noted with that of Christophers. It will be seen that several of the groups are roughly characteristic of special geographical regions.

"Group A (*Neomyzomyia*). Female with buccopharyngeal armature consisting of a single row of large pectinate teeth. One or more propleural hairs present; no spiracular hairs (except in the African species). Pronotal lobes with a tuft of scales (except in *A. nili* and sometimes in *A. tessellatus*). Wings usually with numerous small dark dots on all the veins (but this type of marking not shown in the African species). Legs with the femora and tibiæ nearly always conspicuously speckled or ringed; if the legs are completely dark the female palpi are pale at the tip only (*nili*) or dark-tipped and only faintly ringed (*smithi*). Abdomen with or without scales dorsally, but without lateral scale-tufts. Larva with all the long hairs in the pleural groups simple.

"This group is specially characteristic of the Malayan region, and includes all the Australian species of the subgenus; several African species are also placed here, but as noted above these differ somewhat in adult characters. The group shows some points of resemblance to the subgenus *Nyssorhynchus*, and seems to be the most primitive group of *Myzomyia*; hence it is placed first, instead of last as has sometimes been done. Although the group is well distinguished by the female mouth and larval pleural hairs, it cannot be distinguished sharply on superficial characters from Group E" (Edwards, 1932).

Adults—Females Only.

1. Second segment of palpi with a small sub-apical white spot ... 2
   Second segment of palpi with apical half mostly white scaled ... 3
   Second, third and fourth segments with narrow apical banding ... 4
2. Proboscis black, apical half pale .. *punctulatus* Dönitz
   Proboscis entirely black, labella pale .. .. *punctulatus* var. *moluccensis* S. & S.
3. Proboscis pale on apical third; abdominal tergites 7–8 with scattered pale scales .. .. *annulipes* Walk.
   Proboscis dark; abdomen densely covered with pale semi-erect scales .. .. *amictus* Edwards
4. Proboscis dark; abdomen not densely covered with semi-erect scales .. .. *subpictus* Grassi

Anopheles bancrofti Giles has not been included in the above table since the black, shaggy palpi and black wings with very few spots render it abundantly distinct from other Australian species.

Larvæ.

1. Inner anterior clypeal bristles frayed, outer densely branched *bancrofti* Giles
   Inner anterior clypeal bristles not frayed, widely separated; outer clypeals lightly branched .. .. *annulipes* Walker
   Outer anterior clypeal bristles not branched 2
2. Inner and outer anterior clypeal bristles lightly plumed .. *amictus* Edwards
   Inner and outer anterior clypeal bristles not plumed 3
3. Inner and outer anterior clypeal bristles very lightly frayed; outer about half the length of inner *punctulatus* Dönitz
   Inner and outer anterior clypeal bristles plainly frayed; outer about two-thirds the length of inner .. .. *punctulatus* var. *moluccensis* S. & S.
   Inner and outer anterior clypeal bristles not frayed; inner widely separated .. .. .. *subpictus* Grassi

Anopheles (*Myzomyia*) *amictus* Edwards.

Bull. Ent. Research, XII, 1921, 71; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 9.

♀.—Head with brownish antennae, base and first four segments with small white scales, last ten segments all about same length and thickness. Proboscis dark brownish-black. Palpi as illustrated for ♂ and ♀. Anterior portion of head covered with white scales, remainder blackish-brown, vertical tuft composed of long white hairs.

Fig. 15.—*Anopheles amictus* Edwards. 1, wing; 2, variation; 3, hind leg ♀; 4, ♀ head; 5, abdomen; 6, larval variation; 7, ♂ palp; 8, ♂ terminalia; 9, larva; 10, leaf of float hair. *After* Swellengrebel and Rodenwaldt.

Thorax with mesonotum covered with numerous white semi-erect scales and scattered brownish hairs, numerous laterally; scutellum with similar scales; *eye-spots*, one on either side, blackish, about opposite the lateral angle.

Wing as illustrated in figure.

Legs: Femora of fore and mid with about six ring-like patches of pale scales, basal half of fore femora swollen, tibiae with alternate patches of white and dusky-brown scales, first tarsal with a small pale patch about its own distance from the base then a pale lateral fleck with rest dusky-brown for about the same distance then a short pale patch, rest dusky-brown with pale lateral flecks to apex which has a distinct whitish apical band, second segment with apical and basal banding, third

with apical and pale banding, fourth with pale basal banding; first tarsus of mid leg with four white small patches and a large white one, the latter about at the base of the apical third, a sub-apical dusky-brown ring, apex white scaled, second and third segments with apical and basal white banding, fourth with basal white banding, fifth dusky-brown: hing legs as illustrated.

Abdomen (Fig. 15): Densely clothed with golden-brown semi-erect scales as in figure and numerous brownish hairs, white scaled beneath.

♂.—Palpi as in figure. Terminalia: Coxite with five parabasal spines, three in one row, slightly above are two subequal spines. Harpago with no distinct lobules; claspette with two or three very short hairs, apart from the apical hair—these are less than half the length of the apical hair; phallosome with two groups of four leaflets, the longest about half the length of the phallosome.

Larva: Inner anterior clypeal hairs widely separated, about twice the distance between the bases of the inner and outer clypeal bristles, outer clypeal bristle about two-thirds the length of the inner, both of them frayed, posterior clypeals simple, about half the length of the inner clypeal bristle. Inner occipital hair simple, outer with three branches. Inner shoulder hair with six to seven branches originating near the base, middle on a distinct tubercle and with eleven to twelve branches, outer rather long, simple; palmate bristles on II–VII, with fourteen to twenty leaflets, filament about the length of the blade and tapering to a fine point; angle of shoulder not pronounced. The long propleural hair plumed, two somewhat shorter ones not branched; one mesopleural plumed and one without plumes; metapleural has plumes.

I have been unable to make out the structure of the pecten as larvæ in my possession are all "whole mounts" and not in the best state of preservation.

Distribution.—Recorded from as far south as Brisbane and Cunnamulla in Queensland; Northern Territory: Darwin; Katherine; New Guinea.

Relation to Disease.—Evidence is lacking as to the part this species plays in relation to malaria in Australia and New Guinea.

It is an efficient intermediary host of *Wuchereria bancrofti.*

Anopheles (*Myzomyia*) *annulipes* Walker.

Insecta Saundersiana, Diptera, Part V, 1856, 433; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 9.

♂, ♀.—Head: Frontal tuft conspicuous, composed of long white hairs; base with dusky upright-forked scales, white ones elsewhere, border bristles blackish; palpi dusky-brown, markings as illustrated; antennæ brown, tori paler, first flagellar segment and tori with small white scales on their inner surfaces; proboscis dusky-brown with about the apical half in the ♀ creamy-yellow, apex usually with a very narrow dark ring, labella creamy-yellow, in the ♂ the proboscis is entirely dusky-brown.

Fig. 16.—*Anopheles annulipes* Walker. ♀ head ; ♂ palp.

Thorax : Scutum without eye-spots, clothed with scattered semi-erect white scales and light brown hairs, scutellum with scattered white semi-erect scales, border fringe light brown.

Wings as illustrated.

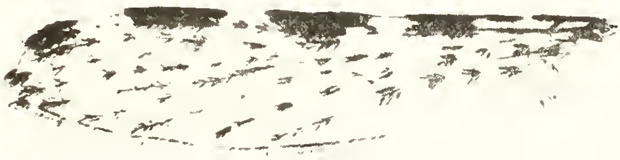


Fig. 17.—*Anopheles annulipes* Walker. Wing.

Legs : Femora and tibiæ with numerous creamy-yellow equidistant bands, first tarsals with about six pale creamy-white spots, tarsus I with apical creamy-white banding, II with basal and apical similar banding, III with basal banding, IV–V without ornamentation.

Abdomen : Brown, densely clothed with brown hairs, last two segments with scattered semi-erect white scales ; ♂ terminalia : coxite with the accessory spine, from its base, longer than the remaining length of the coxite ; harpago bluntly rounded ; four stout parabasal spines, three in a row, the fourth about opposite the middle spine, all with hooked apices ; harpago with club on dorsal lobe slightly swollen apically, apical bristle slightly less than half the length of the club ; longest leaflet, broad with smooth edges.

Larva.—Brown with the pigment arranged in a definite pattern ; antennæ with a short sublateral spine about its middle length ; inner anterior clypeal hairs well apart, much nearer the outer anterior clypeal hairs than to each other, somewhat frayed ; outer anterior clypeal hairs about two-thirds the length of the inner and strongly plumed ; posterior clypeal hairs are wider apart than the inner anterior, are four-branched, short, and not projecting as far as the anterior border of the head ; inner occipital hair trifid, the outer with few plumes.

Distribution.—Very widely distributed in Australia, although it is not common in the northern portion ; Tasmania.

The first specimens of this species to be made known to science were described by Walker in 1856 and came from Tasmania, probably from Hobart.

Ecology.—This species will bite at any time of the day, in secluded spots, or night, most freely at sunset and for about two hours after. Adults enter houses quite freely.

It breeds in all clean or muddy, but not foul, ground water, casual or permanent, along the grass grown banks of creeks and rivers, etc.

Relation to Disease.—This species is capable of transmitting benign tertian malaria, but it does not appear to be an efficient intermediary host under normal circumstances.

Theobald (1901) and Edwards (1924) were in error when they stated that the proboscis was dark (Theobald) or with an ill-defined pale ring beyond the middle (Edwards) for the original description, poor as it is, distinctly states "*proboscis ex parte testacea*".

Anopheles (*Myzomyia*) *punctulatus* Dönitz.

Insekten Borse, XVIII, 1901, 372 ; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 10.

♀.—Head with apical half of proboscis creamy-white to yellowish with a brownish ring immediately before the base of the labella ; palpi of female with a dorsal patch of pale scales toward the base of the second segment, apex with a narrow pale band, apical half of third segment pale with a discoloured spot subapically, rest dusky-brown with a small sub-basal pale spot, fourth segment with a narrow brownish-black band as also the fifth segment, remainder creamy-white.

Thorax: Scales on the anterior prothoracic lobes are sparse, those on the mesonotum appear to be narrower than in var. *moluccensis*.

Wings and legs are similar to those of var. *moluccensis* ; tarsal V of fore leg may be dark, or there may be pale scales mixed with the dark ones ; the basal banding on III–IV of mid legs may be absent, tarsal III and sometimes IV of hind legs may also be spotted.

Abdomen similar to that of var. *moluccensis*, scales only on segments VII and VIII, coxites also covered with scales ; all segments covered with pale hairs.

♂.—Head with palpi as figured. Terminalia as figured.

Larva.—Shoulder hair small, unpigmented, not on a "plate" as in var. *moluccensis* as in figure. Inner and outer anterior clypeal hairs not frayed, the outer about half the length of the inner ; inner occipital hair not branched ; leaflets of palmate bristles pigmented, smaller than in var. *moluccensis*, filament one-third the length of the blade, shoulder well marked.

Distribution.—As for var. *moluccensis*. Type localities were Bogadjim (Stephansort) near Madang and Kokopo (Herbertshoe) on Blanche Bay, New Britain.

Bionomics.—As for var. *moluccensis* and like it in feeding habits—both the typical form and the variety will feed at any time of the day, provided the sky is overcast.

Both are small, grey mosquitoes and do not attract much attention when feeding because their bite is not severe, neither do they make any noise. The typical form, like the variety, enters houses and remains there if undisturbed. It often happens that the typical form is less abundant than the variety *moluccensis*.

There are occasions when both the typical form and the variety appear to be present in almost negligible numbers and yet the malaria may be high. This is also accentuated by the fact that when larvæ are abundant the adults are not at their peak. It is after the larvæ have matured, pupated and the adults emerged when the peak period comes, approximately three to four weeks from the time when the larvæ are seen to be abundant. This is the period that marks the onset of malaria in a district.

Again there is a pre-wet season rise in malaria in New Guinea which subsides at the onset of the wet, remaining in this condition until the end of the wet season, when there is another definite rise, the post-wet season malaria rise, which, like the

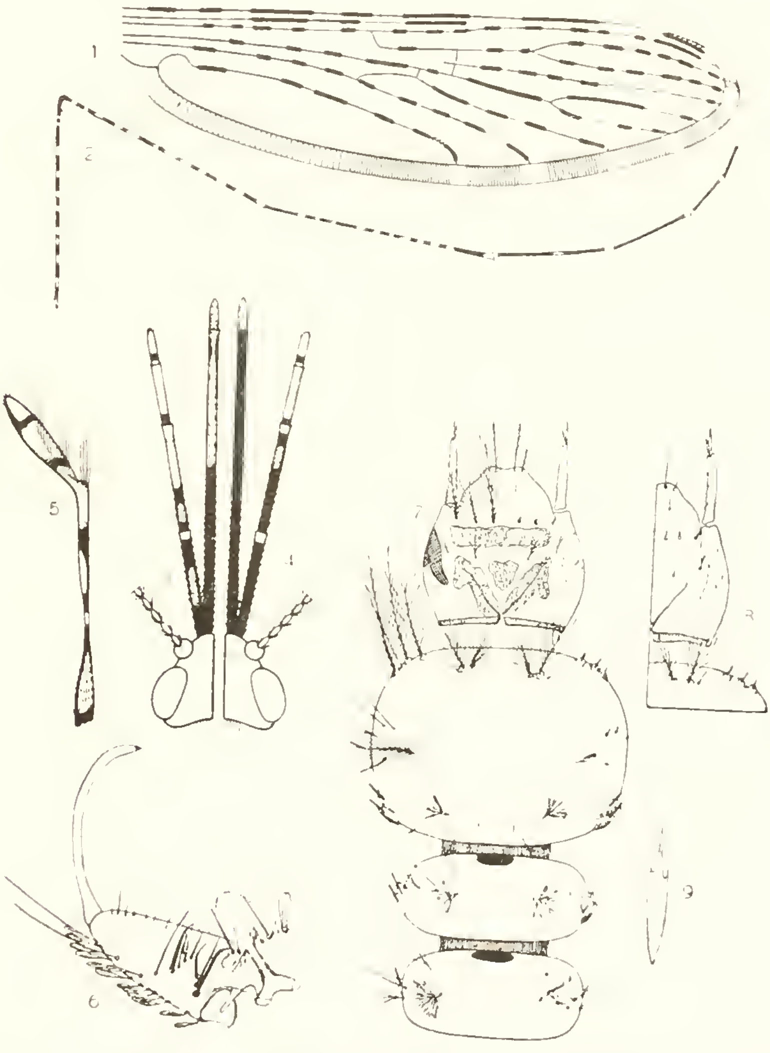


Fig. 18.—*Anopheles punctulatus* Dönitz. 1, wing; 2, hing leg; 3, ♀ head; 5, ♂ palp; 6, terminalia; 8, larva; 9, leaf of float hair. *Anopheles punctulatus* var. *moluccensis* S. & S. 4, ♀ head; 7, larva. *After* Swellengrebel and Rodenwaldt.

pre-wet season rise, may assume epidemic form if there be an influx of new arrivals such as takes place in wartime.

Relation to Disease.—Heydon in 1923 demonstrated that this mosquito and its variety were intermediary hosts of malaria, the former of M.T., and the latter of B.T., M.T., and possibly Quartan.

De Rook in 1924 proved that this species was a carrier of malaria in north New Guinea, finding a natural infection rate of $1\frac{1}{2}$–5% in different months with an abundance of cysts in the stomach.

Many workers have since confirmed that this species and var. *moluccensis* are efficient intermediary hosts.

Anopheles (*Myzomyia*) *punctulatus* var. *moluccensis* Swell. and Swell., de Graaf.

Bull. Ent. Research, XI, 1920, 78; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 10.

♀.—Head covered with white scales, base of head with black ones; antennæ brown, whorls of hair pale; proboscis blackish-brown, labella yellowish-brown; palpi as in figure.

Thorax with anterior prothoracic lobe covered with small black scales; scutum with scattered white semi-erect scales and pale hairs; scutellum with white semi-erect scales; a dark brown spot on either side of thorax about one-third the distance from the anterior margin, and a median one just behind the scutellum.

Wings as in figure.

Legs.—Dusky-brown, very distinctly spotted, the spots forming more or less complete rings; fore leg: femur, tibia and tarsus I spotted, apex of tarsus with broad apical band; tarsi II–IV with broad, pale base and apex; femur, tibia and first tarsal of mid leg with numerous pale bands, second tarsus with a median band, tarsals I–IV with apical and basal pale banding; hind leg as figured.

Abdomen dark brown, covered with pale hairs; segments six and seven with narrow, semi-erect, yellowish-golden scales; sternites seven and eight similar to tergites seven and eight; terminalia somewhat similar to var. *tessellatus* but between the parabasal spines there is rather coarse short hair instead of it being fine. Inwards from the apical hair of the harpago only one short hair, half the length of the apical one, between this and the club are two small hairs.

Larva.—Inner and outer anterior clypeal bristles distinctly frayed, the outer about half the length of the inner; posterior clypeal bristle inconspicuous, about one-quarter the length of the inner clypeal bristle. Outer occipital hair with four small branches, inner with two to three; mid- and inner shoulder hairs dark, stout, with numerous lateral branches; palmate bristles on segments II–VII with leaflets pigmented, blade slightly longer than filament, latter tapering to a fine point, shoulder distinct.

Distribution.—Queensland: Townsville, Cairns, Charters Towers (K. J. Clinton), Hughenden, Mt. Isa, Mareeba, Atherton; Northern Territory: Darwin to Katherine. Probably also in the northern part of Western Australia. Throughout the

Territory of New Guinea, particularly along the coastal areas; Papua; Molucca Islands to the 170° east longitude.

The Queensland localities, except Charters Towers, are from specimens taken by myself. There is no doubt that this variety is very widely distributed in north Queensland. It is probably the commonest mosquito in Katherine, where it breeds in the lagoons and pot-holes along the river banks.

The female freely enters houses to feed; engorged specimens may often be found in considerable numbers in such situations during the daytime.

It will feed at any time of the day if the sky be overcast. I found at Keravat and Pondo in New Britain that it fed freely indoors from the mid afternoon until late at night.

Relation to Malaria.—An important intermediary host of B.T., M.T. and (?) Quartan.

It is also an efficient intermediary host of *Wuchereria bancrofti*.

Bionomics.—Sunlit natural and artificial water, e.g. banks of rivers and creeks, with or without vegetation, drains, trenches, swamps, hoof prints of cattle and horses, puddle holes, and occasionally brackish water pools.

This mosquito follows man when he cuts down and clears away the scrub, thus admitting the sun to ground water which was previously unsuitable to it for lack of sunlight.

Anopheles (*Myzomyia*) *subpictus* Grassi.

Atti d. R. Acad. Lincei, (5), VIII, 1899, 101; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 10; Gater, Aids to the Identification of *Anopheles imagines* Malaya, 1935, 226, Singapore.

♀.—Head: Frontal tuft well marked, ocular scales narrow; second, or basal, segment (torus) occasionally with a few small minute scales, inner side of third segment (flagellar) with white scales. Palpi somewhat shaggy, apical segment about half the length of the penultimate, segments two, three and four with narrow pale apical bands, fifth segment wholly pale, about the same length as the pre-apical dark area; labium uniformly dark.

Thorax: Pale with darker median and lateral areas; two to three propleural hairs; median area covered with short, golden, curved hairs, median and lateral tufts of narrow white scales on the anterior promontory of mesonotum, below latter there are numerous erect black scales.

Wings: Pale, costa with the two pre-humeral dark spots sometimes joined, middle dark spot about twice the length of the pre-apical, dark area on first vein shorter than that on costa, sometimes a small dark spot present on first vein basal to the dark area. Pale areas much more prominent than dark areas, as shown in Fig. 19.

Legs: Fore femora distinctly swollen basally, with a narrow, dark, basal ring, ventral surface often dark or pale basally; mid and hind femora markedly pale beneath except at base and apex; all femora with a double pale spot toward apex dorsally, apices dark; fore tibiae broadly pale beneath, with a thin pale line on outer surface; mid and hind tibiae similar with a thin

pale line expanding at apex. Fore tarsi with broad apical and basal banding, involving the joints, of tarsi one and two, two and three, three and four, fifth of fore and mid legs with narrow basal banding, fifth unbanded in the hind legs.

Abdomen pale, covered with dense golden hairs and some narrow yellowish scales ; occasionally dark ones may be present, on posterior margins of VII and VIII ; ventral surface of VII with scattered pale scales laterally and numerous dark hairs, usually some dark scales in the mid line apically.

♂.—As female. Palpi as in figure. Abdomen covered with hairs, except dorsum of VIII, which is clothed with numerous fairly broad scales ; coxites with numerous dark and pale scales. Harpago of terminalia with very long apical spine, more than twice length of club ; a small spine, less than one-quarter length of apical spine between the latter and the club. Phallosome rather strongly bent ; about one-third length of coxite with about six to seven leaflets on each side, largest leaflet about half the length of the phallosome, leaflets blade-like, some shallow serrations at the base of the larger ones.

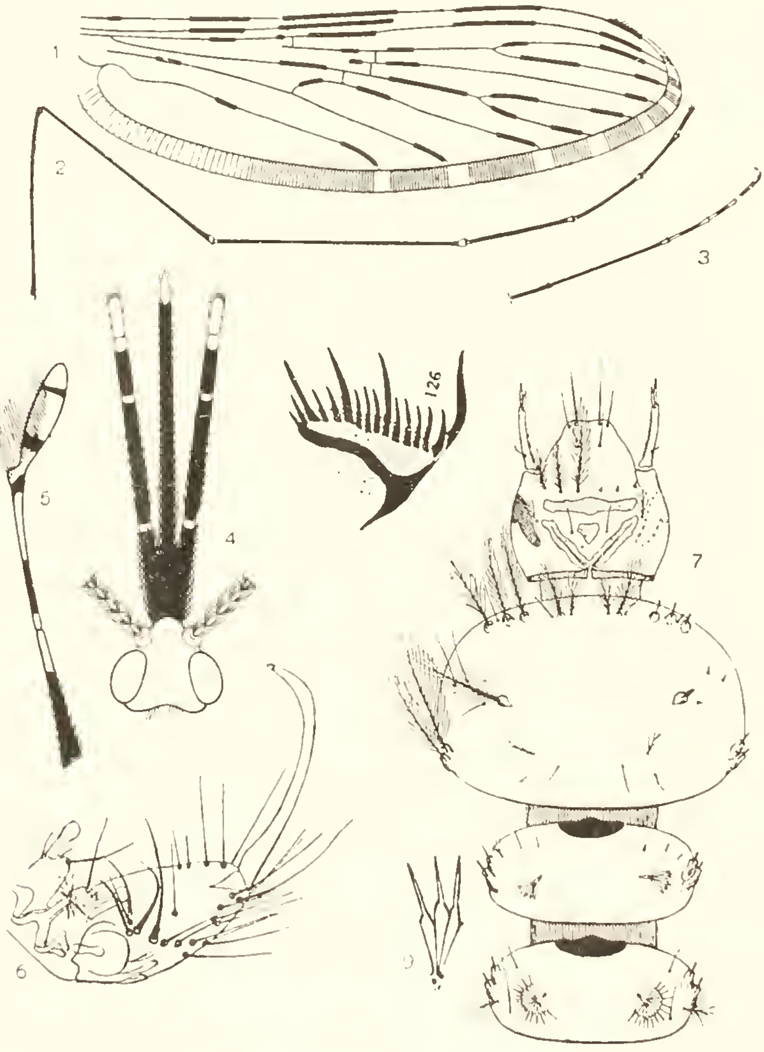


Fig. 19.—*Anopheles subpictus* Grassi. 1, wing ; 2, ♀ hind leg ; 3, ♂ tarsals of hing leg ; 4, ♀ head ; 5, ♂ palp ; 6, ♂ terminalia ; 7, larva ; 8, pecten ; 9, leaf of float hair. *After* Swellengrebel and Rodenwaldt, and Barraud.

Larva : Clypeal hairs slender, simple ; *oc* slightly more than half the length of *ic* ; *pc* slightly shorter than *oc*. Antennæ rather slender ; hair arising about middle of antenna ; terminal hair with three to four branches. Maxillary palp with the cone bifid from about its middle. Mentum with four teeth on either side of median tooth, all adequal and equidistant except last in row, latter tooth somewhat smaller.

Inner shoulder hair without conspicuous basal tubercle, slender, sparsely feathered ; middle with poorly formed tubercle, about one and a half times the length of the inner. Metathoracic hair 1 resembling ordinary hair, short, simple, or split into two to five branches. Palmate hairs well developed on II–VII ; hair No. 1 on I with six to nine poorly developed filaments. Leaflets uniformly but scarcely pigmented ; filament nearly as long as blade, shoulder well defined. Lateral hairs on IV–VI long, splitting near base into three slender branches ; on VII very short, split into two to three branches. Tergal plates very small and narrow. Spiracular chitinization (*spc*) well developed, with projecting spur. Pecten with four to five long, and ten to eleven short processes. Post spiracular hair (*ps*) long, with five to six branches, arising near base ; outer submedian caudal hair with six to eight long branches forming poorly-developed hooks with very shallow curves ; anal papillæ rather stout, twice as long as anal segment.

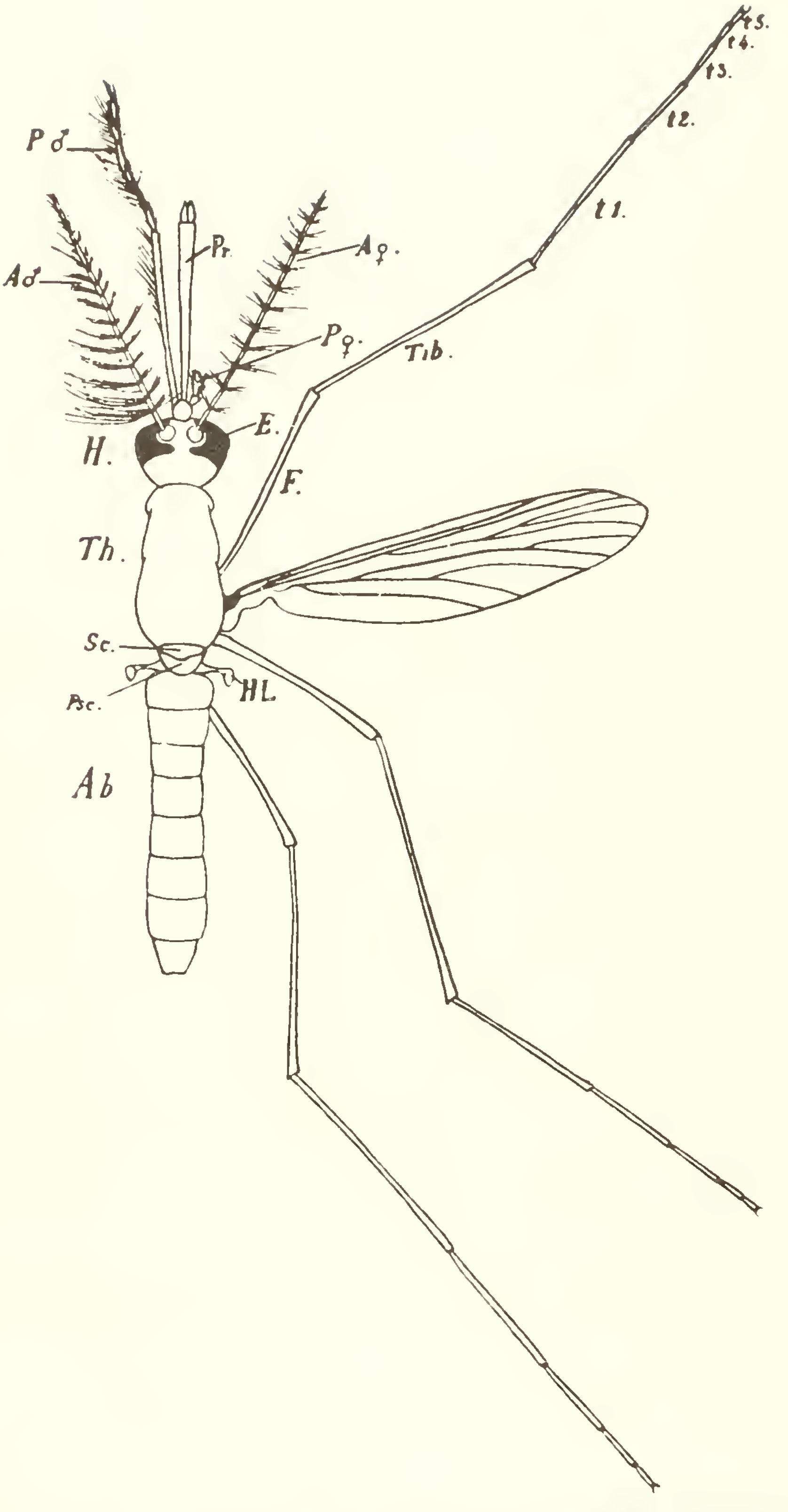
Pupa : Paddle with external border bare on anterior quarter, followed by some short denticles, becoming rather short stout spines posteriorly, replaced abruptly by hairs decreasing in size, not reaching paddle-hair, latter long, hooked ; accessory hair simple. Spine on VIII somewhat less than half segment, and on V–VII curved, pointed, those on VI and VII somewhat more, that of V slightly less than half length of segment. III–IV short, blunt. Hair *B* branched on III–VII ; *C* on V–VII, simple, somewhat longer than segment ; on IV with two to three branches, about length of segment, on III with four to six branches, shorter than segment. *C'* on VI simple. *T* on I simple.

Distribution.—Papua, Netherlands East Indies, Malaya and India.

Bionomics.—Breeds in brackish and fresh water swamps, often muddy rain water pools, and pools contaminated with sewage. " This mosquito, although it prefers the blood of cattle, enters houses and behaves as a typical house mosquito, remaining also during the daytime " (Swellengrebel and Rodenwaldt, 1932).

Relation to Disease.—It is an intermediary host of B.T., M.T., and Quartan malaria. It has not been considered an efficient transmitter of malaria. Swellengrebel and Rodenwaldt (1932) state : " As far as Java is concerned, one must, indeed, be very careful with any judgment as to the significance of *A. subpictus* . . .

" It is probable that *A. subpictus*, in Java, is only of moderate importance. Indeed, in Java the most important part of a campaign against an epidemic has been done after the suppression of *A. ludlowi* even if *A. subpictus* can still be found, but, as mentioned above, this is not always the case.



—*After* Kirkpatrick.

H., head ; *Th.*, thorax ; *Ab.*, abdomen ; *E.*, eye ; *Pr.*, proboscis (labium) ; *A*♂, antennæ of male ; *A*♀, antennæ of female ; *P*♂, palpi of male ; *P*♀, palpi of female ; *HL.*, haltere ; *Sc.*, scutellum ; *Psc.*, post-scutellum ; *F.*, femur ; *Tib.*, tibia ; *t*1-*t*5, tarsal segments.

"The position is different in Celebes. There *A. ludlowi* is absent in wide stretches of the west and south coast, whereas *A. subpictus* is abundant because of the large brackish-water swamps, and lagoons. There, despite its relatively low natural infection (Rodenwaldt, Makassar 0·5; Kundig 0·3) *A. subpictus* without any doubt is the sole source of infection. That is to say that so far there are no indications that *A. parangensis* is of any importance. This is proved quite clearly by the reclamation by drainage of the lagoons and brackish water swamps at Boeloekoemba, Baroe and Makassar" (Swellengrebel and Rodenwaldt, 1932).

According to Soewadji Prawirohardjo (1939) this mosquito is an efficient intermediary host of *Filaria bancrofti*.

CULICINE ESSENTIAL MORPHOLOGY.

Tribe Culicini.

"*Characters.*—Adult: Clypeus longer than broad, rounded above and in front. Proboscis uniformly slender and flexible, or somewhat swollen at tip, not hooked. Mandibles and maxillæ in ♀ (except in *Harpagomyia* and perhaps one or two other genera) reaching as far as end of labium and provided with a series of teeth apically. Labella not elongate. Thorax rather strongly arched above, scarcely longer than broad; scutellum always trilobed, each lobe bearing bristles, but areas between lobes without bristles. Abdomen completely clothed with broad scales which nearly always lie flat on the surface. Hypopygium of ♂ variously constructed, but anal segment always with well-developed paraprocts and ædeagus never with leaflets at its tip. Female usually with three spermathecæ. Legs less slender than in Anophelini; tibiæ usually with scattered bristles. Wings with cell R_2 seldom much shorter than its stem: base of R_{4+5} usually oblique; cross-vein *r-m* vertical, not bent at right angles; no distinct spur extending basally from angle of R_{4+5}; no emargination of hind margin and no thickening of membrane between branches of *Cu*.

"*Pupa.*—Abdominal segments 2–6 with the lateral hairs placed some distance from the apical corner, and always different in character from those of segments 7 and 8, which are closer to the corners of the segments and often similar to one another, and branched from the base; tuft of segment 8 often larger than that of segment 7. Paddles usually with a hair or tuft at tip of midrib; if a second hair is present (as in *Culex*) it it placed near the larger hair and not farther back as in Anophelini. Outer portion of paddle never produced distinctly beyond end of midrib.

"*Larva* (Fig. 33).—Head variously shaped, often large, usually non-rotatable. Clypeus usually with a pair of spines or bristly hairs on front margin, and with four pairs of hairs, two of which (*B* and *C*) are usually larger than the others and placed near middle of dorsal surface of head. None of the hairs of the body are pinnately branched as in Anophelini; frequently the larger hairs, and often also many of the smaller hairs of the head, thorax and abdomen are branched in a fan-like or stellate manner from the base; the individual hairs of the tufts may often be shortly plumose. Antennæ variously formed, but

never with two stout terminal spines with a hair between, as in Anophelini, or with three similar hairs on shaft, as in Megarhinini. Mouth-brushes composed of a large number of hairs, which are often finely pectinate along one side; in the predaceous species the number of hairs in the mouth-brush may be reduced, but is never less than about thirty, and their bases are never arranged in one line as in Megarhinini. Mentum usually triangular, seldom longer than broad, median tooth usually the longest. Thorax broad or moderately broad. No eversible appendages on front margin of prothorax. Chaetotaxy variable in different genera and subgenera. Propleural hairs usually if not always four in number, but variable in development; mesopleural group with three long hairs, metapleural with two long hairs and one shorter hair, fourth hair very often absent in both (present in at least some genera of the *Sabethes* group); one or two of the long mesopleural and metapleural hairs usually branched from base. Abdomen without float-hairs; chætotaxy otherwise very variable. Eighth segment with a postero-dorsal air-tube (siphon); a lateral chitinous plate may or may not be present, but there is always some trace at least of a lateral comb (except in *Trichoprosopon*). Siphon with or without pecten; at its tip are the same five plates (a fixed anterior median piece, a smaller anterior and a larger posterior pair of movable valves) as occur in the Anophelini. On side of eighth segment posteriorly are five hairs or hair-tufts. Anal segment with one or both pairs of dorsal hairs usually branched from base; ventral brush (when present) with all the hairs of the same type, branched from near base.

"*Eggs.*—Variously shaped, but never roundedly oval, as in Megarhinini, or provided with lateral floats, as in Anophelini" (Edwards, 1932).

CHARACTERS USED IN IDENTIFICATION AND CLASSIFICATION.

PROBOSCIS (LABIUM).

The *proboscis* (Fig. 21) is a hollow sheath which acts as a covering for the mouth parts, which in the female comprise two mandibles, two maxillæ, a labrum-epipharynx and hypopharynx. The mandibles and maxillæ are used for cutting the skin of the victim, while all the above form the food channel up which the female sucks its blood-meal; only the female sucks blood. A salivary secretion is injected into the blood as it enters the food channel to prevent clotting. The mosquito draws back its labium (proboscis) so that the apices of the mouth parts become sufficiently exposed for the mandibles and maxillæ to cut the skin of the victim. The blood is drawn up through a channel formed by the mandibles, maxillæ, labrum-epipharynx and the hypopharynx, which is known as the food channel. The above mouth parts are held in a rigid position by the apex of the labium (proboscis), which is known as the labella. The accompanying figure illustrates how the abovenamed parts interlock so as to form a "water-tight" tube (Fig. 22).

THORAX.

"No part of the body is of more importance in classification than the thorax, one reason for this being that the structure is


20


21 a b

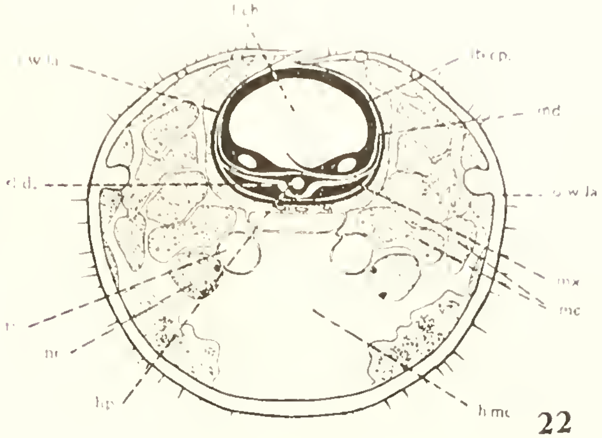

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Fig. 20.—*hm.*, humeral cross-vein ; *C.*, costa ; *Sc.*, subcosta ; R_1, first long vein (radius) ; R_{2+3}, second long vein ; R_{4+5}, third long vein ; *Ma*, *Mp* (M_{1+2}), fourth long vein ; Cu_1, Cu_2, fifth long vein ; A_1, sixth long vein ; *r-m.*, radio-medial cross-vein ; *m-cu.*, medio-cubital cross-vein. Fig. 21 *a*, *b*.—Head of female mosquito. *CL.*, clypeus ; *P.*, palp ; *L.*, labium ; *Lab.*, labella ; *Lbr.*, labrum-epipharynx ; *Hy.*, hypopharynx ; *Man.*, mandibles ; *Max.*, maxillæ. Fig. 22.—Transverse section of proboscis and mouth parts of a mosquito to show the various parts *in situ*. *fch.*, food channel formed by labrum-epipharynx and hypopharynx ; *hmc.*, hæmocœle between the labium (proboscis) in which the embryos of *Wuchereria bancrofti* lie, when ready to leave the labium ; *hp.*, hypopharynx ; *sl.d.*, salivary duct ; *i.w.la.*, inner wall of labium ; *lb.ep.*, labrum-epipharynx ; *mc.*, muscle bundles ; *md.*, mandible ; *mx.*, first maxilla ; *ne.*, nerve ; *o.w.la.*, outer wall of labium ; *tr.*, trachea.

uninfluenced by sex, and the ornamentation only very slightly so. An appreciation of the structure of the thorax and the limits of its different sclerites is therefore essential for determination ; it should be made clear by the accompanying figures and the following explanatory notes (Fig. 29).

" *Prothorax.*—As in all Diptera this is much reduced, but is composed of four main parts : anterior pronotal lobes (*apn*), posterior pronotal lobes (*ppn*), propleura, and prosternum. The *anterior pronotal lobes* (sometimes called simply pronotal lobes) are the prominences lying one on each side of the front of the thorax and protecting the head ; they vary somewhat in size but are always separated above. The *posterior pronotal lobes* (also sometimes referred to as proepimera) form that part of the side wall of the thorax lying between the anterior pronotal lobes and the anterior spiracle, a very small *spiracular area* being separated off from the main portion by a strong ridge. The presence of *spiracular* bristles on this small area distinguishes the genera *Theobaldia* and *Uranotænia*. The bristles and scales on the anterior and posterior pronotal lobes are of taxonomic importance, especially the scales, which may be present or absent, broad or narrow, and often differ in shape from those

of the mesonotum. The term *propleura* is here used for the small portion lying immediately above the front coxa, with a projecting tongue extending round the front of the base of the coxa, and connected with the anterior pronotal lobes by a band; the lower part of the propleura bears setæ which vary in number according to genus, species and sex (*Uranotænia* having the minimum of one propleural seta), but the upper part is always bare. The propleura is sometimes called the 'proepisternum', but as there is no clear division into episternum and epimeron the longer term seems unnecessary. The *prosternum* is the part between the two front coxæ which has not hitherto been studied comparatively. It is usually entirely bare, but sometimes bears scales on its upper part, while in *Dunnius* and *Eretmapodites* it is uniformly and densely scaly; in a few species of *Culex* it bears a number of bristly hairs.

"*Mesothorax: Dorsal.*—Almost the whole of the upper surface of the thorax is formed by the *mesonotum*, which is divided into the scutum, scutellum, postnotum and paratergites. By far the greatest area is occupied by the *scutum*, this name being here used for the combined præscutum and scutum, these parts in the Culicidæ not being divided by any recognizable suture. Just in front of the middle and immediately above the spiracle the lateral margin of the scutum is slightly prominent, forming the scutal angle; in the middle posteriorly is a small area referred to as the *bare space* on account of the absence of vestiture upon it. The scutellum is trilobed in all genera except *Magarhinus*.* The *postnotum* (also called post-scutellum, mesophragma, or, incorrectly, metanotum) is the part behind the scutellum. The paratergite is a small area on each side a little in front of the wing-root and cut off from the scutum by a strong furrow; it varies in size and shape in different genera.

"The scutum bears a *vestiture* of bristles and scales. The bristles are not uniformly distributed, but occur mainly in a *supra-alar* patch above and in front of the wing-root and in two or three longitudinal lines or stripes; those along the median line are the *acrostichal bristles*, those along the other two lines the *dorso-central* bristles; the acrostichal bristles are nearly always noticeably shorter and weaker than the dorso-centrals and are not infrequently entirely absent; in any case they occur mainly on the anterior half of the scutum; the dorso-central bristles also may be absent from the front part of the scutum and present only for a short distance in front of the scutellum, or even (*Megarhinus*) absent altogether. Scales are usually distributed uniformly and rather densely over the surface of the scutum except on the bare space, but in a few cases they are sparse or absent on certain areas, and not infrequently bare lines adjoin the lines of dorso-central bristles. The scutellum bears marginal bristles on each of its three lobes, and usually scales on its dorsal surface, the shape and density of these scales being important for classification, especially in the genus *Aëdes*. The paratergites are usually bare, but in *Aëdes* are clothed with scales, which may be broad or narrow, these scales usually resembling those of the pronotal lobes rather than those of the scutum. The postnotum is bare except in some species of *Eretmapodites*, where it bears a few small bristles.

* and, naturally, excepting the tribe Anophelini. (F.H.T.)

"*Mesothorax: Lateral.*—Apart from the posterior pronotal lobes (defined above), most of the side of the thorax is occupied by the mesothoracic pleurae, comprising the following portions: *Post-spiracular* area, the area immediately behind the anterior spiracle; it is largely membranous, the sclerotized portion being the anterior part of the anepisternite. *Sub-spiracular* area, the membranous area below the anterior spiracle and adjacent to the posterior postnotal lobes and propleura. *Sternopleura*, a large sclerotized area of the lower half of the pleurae between the front and middle coxae. *Pre-alar* area, a narrow upward extension of the sternopleura reaching to just in front of the base of the wing and separated from the anterior anepisternite (post-spiracular area) by a membranous cleft; its upper portion is strongly convex and forms the *pre-alar knob*. *Mesepimeron*, a rectangular area of the posterior part of the pleurae, marked off by well-defined sutures from the surrounding areas; it is also known as the pteropleura or pteropleurite—names which are more frequently used for the corresponding part in some other families of Diptera. *Meron*, a small triangular piece immediately behind and above the base of the middle coxa and below the mesepimeron; in all mosquitoes it is bare and in the African ones has no taxonomic significance.

"The hairs or bristles on the sides of the mesothorax are as follows: *Post-spiracular*, a small group in the middle of the post-spiracular area, found only in the genera *Aëdes* and *Eretmapodites* and in the subgenus *Mansonioides*. *Sternopleural*, a more or less vertical row towards the posterior edge of the sternopleura, sometimes continued forward along the boundary between this and the pre-alar area. *Pre-alar*, a group on the pre-alar knob. *Upper mesepimeral* or subalar, a group in the upper corner of the mesepimeron immediately below the wing-root; these and the pre-alar hairs are almost always present and therefore of little or no taxonomic interest. *Lower mesepimeral*, a small group (or frequently a single hair) below the middle or towards the lower edge of the mesepimeron; very useful in distinguishing many species of *Aëdes* and *Culex*.

"The scales of the pleurae are even more valuable for purposes of specific differentiation than the bristles, a fact which I have not sufficiently appreciated until recently. The scales are usually all of one type, broad and flat, though in some *Aëdes* narrow scales may be present in certain areas. In some genera (notably *Megarhinus*) the pleurae are very much more extensively scaly than in others (e.g. *Culex*, some species of which are almost completely devoid of pleural scales). The presence or absence of scales on the post-spiracular, sub-spiracular or pre-alar areas may provide means of distinguishing between closely related species.

"*Metathorax.*—The metathorax, as in other Diptera, is very much reduced. Its dorsal portion (metanotum) forms a narrow and very inconspicuous strip between the postnotum (which was mistakenly thought by Theobald and some other writers to be true metanotum) and the first abdominal tergite. The pleura of the metathorax is better developed than the notum, forming a rather narrow area (divided into two by a vertical suture) behind the mesepimeron and above the hind

coxa: it is of little or no taxonomic significance. The small piece lying immediately above the hind coxa I have here called the *metameron*; it has been referred to by some writers as the meteusternum, and is the only part of the metapleura on which obvious scales may occur [(as in *Aëdes caspius*)." Edwards, 1941.]

SYSTEMATIC DESCRIPTIONS.

Genus *Tæniorhynchus* Lynch, Arribalzaga.

Rev. Mus. La Plata, I, 1891, 371; *Mansonia* Blanchard, *C.R. Soc. Biol.*, LIII, 1901, 1045.

"*Characters.*—Adult: Eyes almost or quite touching. A continuous row of orbital bristles. Proboscis of moderate length and uniform thickness, not swollen at tip in either sex. Palpi of ♂ as long as proboscis or longer (in the known species); of ♀ not more than one-quarter as long as proboscis. Antennæ of ♂ distinctly plumose, with the last two segments elongate; of ♀ with moderately long verticils, all the flagellar segments (including the first) about equal in length. Vertex with numerous upright forked scales and narrow, curved, decumbent scales, but few or no broad, flat scales except at sides. Thorax usually without striking ornamentation. Mesonotal (acrostichal and dorsocentral) bristles always strongly developed. Anterior pronotal lobes widely separated, rounded and bristly. Several strong posterior pronotal bristles, but no spiraculars; post-spiraculars present or absent; upper sternopleural well developed; lower mesepimeral usually present. Postnotum always bare. Pleuræ usually with only a few small patches of scales. Upper margin of meron well above base of hind coxa. Abdomen: Hypopygium of ♂ rather variable in structure, but always with a lobe or process at base of coxite, which seems to correspond rather with the basal lobe than with the claspette of *Aëdes*. Eighth segment of ♀ always short and broad, cerci short. Legs of moderate length. Tibial bristles usually distinct. Hind tibia with a more or less distinct row of fine hairs on inner side at tip. First hind tarsal segment shorter than tibia; fourth segment of anterior tarsi not unusually short. Claws of front and middle legs of ♂ unequal, larger claw usually with two teeth, smaller usually simple; all claws of ♀ simple. No pulvilli. Wings with many or all of the vein-scales broad, often very broad and asymmetrical. Fork-cells usually long. *Sc* ending well beyond end of *Rs*. *An* reaching far beyond base of cubital fork. No hairs on stem vein, above or below. Squama with complete fringe.

"*Pupa.*—Respiratory trumpet long, the tip peculiarly modified, forming a chitinized spine. No dentritic tuft on first abdominal segment: remaining abdominal segments either with stout single bristles (subgenus *Mansonioides*) or bare (subgenus *Coquillettidia*). Paddles rather long and narrow, emarginate at tip, without fringe or apical hair.

"*Larva.*—Antenna long, spicular, with large branched tuft before middle, and two long or very long bristles inserted far before tip. Mouth-parts not specially modified; mouth-brushes large. Maxillæ with a single long and rather stout apical spine, in addition to the hair-tuft, the spine similar

in length and thickness to the long clypeal spines. Mentum small. Thorax with well developed hair-tufts, including those of the prothorax; mesopleural and metapleural tufts set in distinct but not very large plates. A pair of large tracheal dilatations in thorax. Abdomen without chitinous plates except on anal segment, which is completely ringed and longer than usual. Comb of a few long teeth in one row. Siphon short, without trace of pecten, and with one pair of hair-tufts near tip (or, if valves are reckoned in length of siphon, about middle). Valves peculiarly modified; the small anterior valves each bearing a stout curved bristle; posterior pair elongate, fused, forming a sheath for a complicated internal apparatus which includes a strongly chitinized saw. Both inner and outer dorsal hairs of anal segment branched. Ventral brush well developed.

"*Eggs.*—Elongate, usually with a long neck, sometimes with branched processes.

"*Habits.*—The larvæ of all species of this genus occur in over-grown swamps or ponds, and derive their air from the roots of water-plants, which they pierce by means of the saw-apparatus in the siphon; they attach themselves firmly to the roots of the plants and seldom if ever come to the surface to breathe. In the case of the subgenera *Tæniorhynchus* and *Mansonioides* floating aquatic plants are affected, but in *Coquillettidia* and perhaps *Rhynchotænia* the larvæ are found in the mud among the roots of grasses, bulrushes and other plants. Pupæ also derive their air from the same source, piercing the rootlets with the spine-like tips of the respiratory organs and remaining below until ready for emergence, when they rise to the surface. In the case of *Coquillettidia* the tip of the trumpet breaks off and remains in the plant, but in *Mansonioides* it is withdrawn. In the holarctic species hibernation takes place in the mud in the larval state, the thoracic air-reservoirs doubtless being used during this period. Eggs are either laid in raft-like masses on the surface of water (subgenera *Coquillettidia*, *Rhynchotænia*) or in small groups on the under-surface of leaves of floating water-plants (subgenera *Tæniorhynchus*, *Mansonioides*). The species often occur in great numbers and the females are troublesome blood-suckers.

"*Classification.*—Considerable differences are found in different species not only in the form of the male palpi and of the male and female genitalia, but also in the pleural chætotaxy and the shape of the wing-scales. The remarkable specializations of the larval siphon however are practically alike in all the known species; it therefore seems certain that they are all closely related, and that the differences in the adults are not of more than subgeneric value."

Subgenus *Mansonioides* Theobald.

Mon. Cul., IV, 1907, 498.

"*Characters.*—Palpi of ♂ about as long as proboscis, not swollen apically and only moderately hairy; penultimate segment rather long and strongly upturned, terminal segment minute. Hypopygium of ♂ with a long process arising from the base of the short coxite; style apparently without terminal spine, rather short and broad; paraprocts with several terminal

teeth; phallosome simple, undivided. Abdomen of ♀ with the seventh segment reduced, much smaller than sixth; eighth quite concealed, with a number of chitinous hooks as in subgenus *Tæniorhynchus*; only two spermathecæ. In both sexes post-spiracular bristles are present; wing-scales mostly or all very broad and asymmetrical (Fig. 24).

"*Larva.*—Antenna of moderate length; subapical spines very long, inserted far beyond middle of antenna, terminal portion less slender than in the other subgenera. Frontal hairs *B* and *C* minute, scarcely distinguishable. Several small ventral tufts on anal segment before the barred area."

Distribution.—Chiefly oriental, but two species are abundant throughout tropical Africa, two species in Australia, three on the mainland of New Guinea and one extending also into Japan.

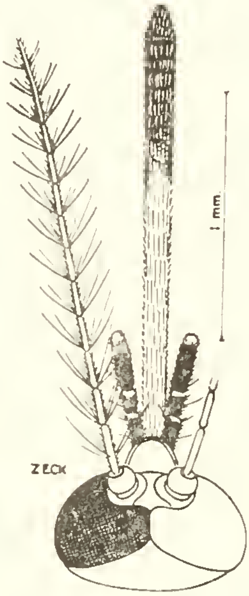


Fig. 23.—*Tæniorhynchus* (*Mansonioides*) *uniformis* var. *australiensis* Giles. ♀ head.

Tæniorhynchus (*Mansonioides*) *uniformis* var. *australiensis* Giles.

Handbook Gnats, 2nd Ed., 1902, 355; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 14.

♀.—Head with silvery-white narrow-curved and black upright-forked scales on the vertex and nape, silvery white ones round the eye margins, some broad pale ones toward the base at sides; antennæ brown with inconspicuous pale rings, first flagellar segment yellowish, tori yellow; palpi about one-third the length of the proboscis with scattered brown and yellow scales, those at apex whitish in colour; proboscis with apical third dark brown, flecked with few yellowish scales, remainder mainly yellow with a few yellowish-brown, scattered scales.

Thorax: Mesonotum densely covered with dark-golden brown and pale silvery narrow-curved scales, the latter in the form of two sublateral stripes from the anterior margin to above

the wing roots, and a median somewhat grey, narrow line, only seen in some lights, on the posterior third a broad median stripe of pale silvery narrow-curved scales extends from the posterior margin of thorax to in front of the wing-roots, the anterior end being bluntly rounded: scales on the scutellum pale silvery and narrow-curved; pleuræ brown with several patches of broad white scales, some narrow pale ones on the posterior pronotal lobe: lateral bristles golden brown.

Legs: Fore and mid femora with oblique pale markings, hind femora with similar but more conspicuous markings, tibiæ with confluent pale markings, tarsal markings yellowish.

Wings as illustrated.

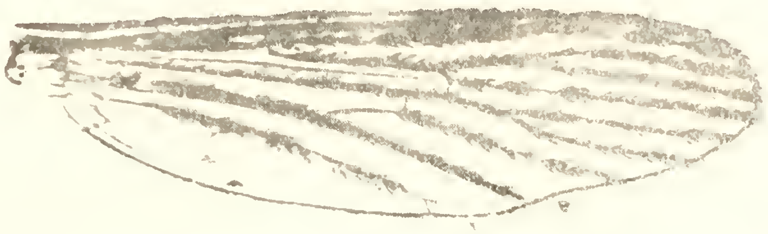


Fig. 24.—*Tæniorhynchus* (*Mansonioides*) *uniformis* var. *australiensis*. Giles. Wing.

Abdomen: First segment with golden scales in the centre, blackish laterally; second and third segments black scaled each with a median basal patch of golden-yellow scales, that on the third about half the size of that on the second, remaining segments black scaled with a very few scattered yellowish ones, segments II–VII with lateral apical white patches extending ventrally, eighth golden yellow; venter with basal three segments dark scaled, remainder golden to white according to the angle of light. Some specimens have all the tergites covered with blackish scales, even the white lateral, apical spots scarcely showing.

♂.—Palpi about one and one-third times as long as proboscis, brown, a broad white band approximately opposite the middle of the proboscis, base of penultimate segment with an indistinct pale spot, apical segment very small, pale; antennæ about length of proboscis, plumes brown; thorax as in ♀; abdomen similar to that of ♀, but somewhat more mottled apically; venter pale scaled.

Distribution.—This mosquito extends as far south as the Murrumbidgee River district in New South Wales. I have no South or Western Australian records, its range is probably co-extensive with that in New South Wales.

Bionomics.—The members of the subgenus *Mansonioides* are peculiar in that their larvæ and pupæ extract their oxygen from the rootlets of water plants—the rootlets being pierced by the apex of the siphon (larva) or breathing trumpet (pupa) which is specially modified for the purpose.

The adults are very fierce day and night biting mosquitoes both in the bush and in houses, which they enter freely. Their

range of flight is certainly more than half a mile without the assistance of the wind. Specimens entered my bedroom when I was in Cairns, June-July, 1942, the nearest breeding ground being a little more than half a mile away.

Relation to Disease.—The typical form, *M. uniformis*, is an intermediary host of *Wuchereria malayi* and therefore the variety may also be capable of transmitting the larva. It is included in this publication since it is possible that the above worm may have been introduced into Australia.

Originally described as a distinct species by Giles but later sunk as a variety by Theobald, Edwards and others regarded it as a synonym of *uniformis*, but there are sufficient characters to separate it as a variety. It seems doubtful that typical *uniformis* occur in Australia, if such be the case then *australiensis* will rank as a subspecies.

A description of the larvæ and pupæ is not given as I have none from Australia. S. H. Christian has supplied me with larval and pupal material taken at Ambunti, New Guinea. The lateral chitinous hooks of the female and the male terminalia are not described as they form the subject matter of another publication.

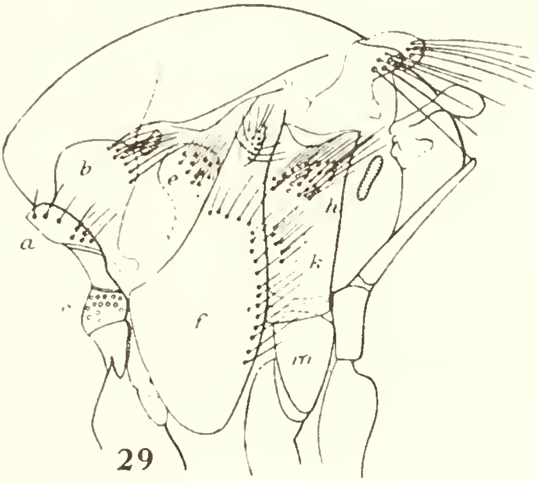
Genus *Aëdes* Meigen.

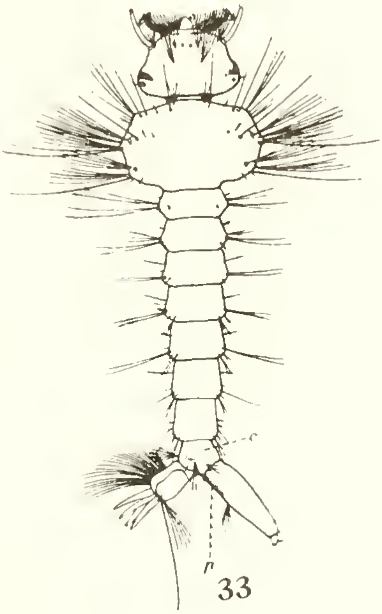
Syst. Beschr., I, 1818, 13; Dyar and Knab, *J. N.Y. Ent. Soc.*, XIV, 1906, 188.

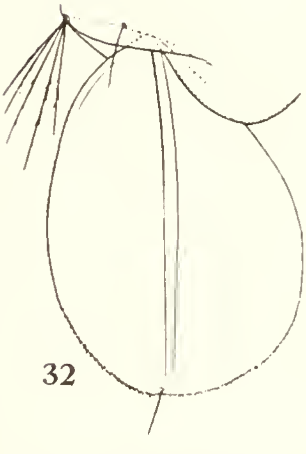
"*Characters.*—Adult: Eyes usually separated above by a narrow line; sometimes wider apart, rarely actually touching. A continuous row of orbital bristles bordering eyes. Proboscis of uniform thickness throughout, not swollen at tip in either sex, and not distinctly bent back in repose. Palpi of ♂ rarely longer than proboscis, sometimes quite short; of ♀ rarely more than one-quarter as long as proboscis (over half as long as proboscis in *A. fulgens*). Antennæ of ♂ nearly always distinctly plumose, with the last two segments elongate; of ♀ with moderately long verticils, all the flagellar segments (including the first) about equal in length. Scales on upper surface of head very variable in arrangement and form according to species; upright scales on nape usually numerous, but sometimes much reduced in number. Thorax (Fig. 29) with ornamentation very variable. Mesonotal bristles well developed; several pre-scutellar hairs always present (except in subg. *Dunnius*). Pronotal lobes widely separated. Posterior pronotal lobes ('pro-epimera') with about 4–6 bristles (sometimes rather more), in a posterior row overlapping the spiracle. Spiracular bristles absent. At least two or three post-spiracular bristles (Fig. 29*e*) always present; pre-alar, sternopleural and upper mesepimeral bristles present and rather numerous; lower mesepimeral bristles present or absent. Postnotum without setæ. Pleuræ usually extensively scaly. Upper margin of meron above level of base of hind coxa (Fig. 29*m*). Abdomen: Hypopygium of ♂ variable in structure (see under subgenera), but anal segment always rather simple, without teeth, spines or hairs at tip of paraprocts. Eighth segment of ♀ abdomen usually more or less retractile; cerci often long. Legs moderately slender; femora and tibiæ usually with more or less

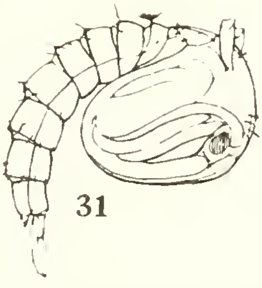
distinct scattered bristles. Hind tibia on inner side at tip with a close-set row of hairs. First segment of hind tarsus distinctly shorter than tibia (except in *A. aurimargo* and *A. longirostris*). Claws of front and middle legs of ♂ unequal, usually each with one tooth; of ♀ (Fig. 30) usually toothed. Pulvilli (*p*) absent or hair-like (Fig. 30), never broad and distinct. Wings with cell R_2 usually about as long as its stem, seldom much longer or shorter. *Sc* usually ending almost opposite end of *Rs*, but sometimes longer. Vein *An* ending well beyond base of cubital fork. Cross-vein *m-cu* well before *r-m* (except in subgenus *Mucidus*). Membrane with distinct microtrichia. One or more hairs usually present on upper surface of stem vein, none beneath. Alar squama with complete fringe of hairs.

" *Pupa* (Fig. 31).—Without special modifications. Respiratory trumpet usually short, with small opening. Dendritic tufts on first abdominal segment well developed. Paddles (Fig. 32) often somewhat pointed; a single apical hair which is usually of moderate length and may be branched; margin usually more or less serrate or fringed.









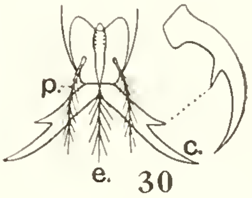


Fig. 29.—Lateral view of thorax of *Aëdes* to show pleural sclerites and arrangement of bristles. (*a*) Anterior pronotal lobe, with bristles; (*b*) posterior pronotal lobe, with numerous bristles; (*c*) propleura, with bristles; (*e*) post spiracular, with bristles; (*f*) sternopleura, with numerous bristles; (*h*) subalar knob, with bristles; (*k*) mesepimeron with bristles on lower part; (*m*) note meron in relation to hind coxa. Fig. 30.—Tarsal characters of genus *Aëdes*: toothed claws, rudimentary pulvilli (*p.*); *e.*, empodium. Fig. 31.—Side view of *Aëdes* pupa. Fig. 32.—Pupal paddle with seta of *Aëdes* (*Stegomyia*) *aegypti*. Fig. 33.—Larva of *Aëdes*: *c.*, comb; *p.*, pecten.

"*Larva* (Fig. 33).—Mouth-parts (except in subgenus *Mucidus*) not specially modified for predaceous habits, but inner hairs of mouth brushes usually more or less serrate. Mandibular teeth (except in subgenus *Mucidus* and in some *Ochlerotatus* and *Finlaya*) small and not blackened. Antennal tuft usually at or before the middle. Thoracic hairs variable, but the inner shoulder-hairs and the propleural group but little developed; usually only one long simple hair in the propleural group, the other three shorter. Plates of meso- and metapleural hairs usually small. No air-sacs in thorax. Abdomen without dorsal chitinous plates except on anal segment which usually has a dorsal saddle, rarely a complete chitinous ring. Siphon unmodified, at most four times (usually scarcely twice) as long as breadth at base, always with well-developed pecten and with a single pair of ventral hair-tufts placed near or beyond middle; rarely with a few accessory dorsal hairs or tufts. Outer pair of hairs at tip of anal segment long and simple, inner usually shorter and branched. Ventral brush of anal segment usually well developed, but sometimes reduced to a few hairs (at least 4–6).

"*Eggs* (Fig. 34).—Somewhat spindle-shaped or elliptical, thick-shelled, usually with fine, more or less hexagonal sculpturing on surface, but without spiny processes.

"*Habits.*—Varying much in the different subgenera and species, but eggs always laid singly, and very resistant to desiccation, sometimes capable of lying dormant for several years. Larvæ in various types of water, usually feeding mostly at the bottom. Females usually active blood-suckers, biting by day" (Edwards, 1932).

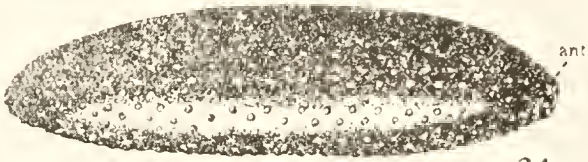


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Fig. 34.—Egg of *Aëdes* (*Stegomyia*) *ægypti*, highly magnified; *ant.*, anterior pole. Fig. 35.—Head of *Aëdes* (*Stegomyia*) *albopictus* to show form of ♂ palpi and antennæ of subgenus *Stegomyia*. Fig. 36.—*Aëdes* (*Stegomyia*) *ægypti*. Aedeagus showing divided phallosome.

Subgenus *Ochlerotatus* Lynch, Arribalzaga.

Rev. Mus. La Plata, I, 1891, 371; *op. cit.*, II, 1892, 143.

Characters.—Ornamentation rather varied, but scales of vertex and scutellum always narrow, usually also those of pronotal lobes. Proboscis slender, longer than front femora. Palpi of ♂ almost or quite as long as proboscis, usually distinctly longer; last two segments swollen, hairy, not upturned but either projecting straight forwards or turned slightly downwards. Antennae of ♂ with the plume-hairs directed mainly dorsally and ventrally. Several lower mesepimeral bristles present in most species. Anterior claws always toothed in both sexes, usually also the hind claws. Eighth segment of ♀ abdomen small and completely retractile; cerci long and narrow. Hypopygium: Coxite long, with distinct basal lobe and usually also with more or less developed apical lobe. Claspettes present, usually well developed, with columnar stem and flattened appendage; rarely less developed, with appendage setiform. Style long, slender, flattened, with terminal spine. Phallosome simple, smooth, not divided into lateral lobes. Ninth tergite with two small bristly lobes placed close together.

Larva.—Antennae more or less spiracular, with branched hair near middle of shaft. Frontal hair *B* in front of *C*. Siphon usually over twice as long as its breadth at the base; tuft rarely much beyond middle (sometimes before middle); pecten rarely with detached teeth apically; acus present or absent. Comb-teeth usually in a triangular patch, sometimes reduced in number and in a more or less regular row. Plate of anal segment often large, in fourth-stage larvae not infrequently forming a complete ring. Ventral brush always well developed, often with accessory tufts before the barred area; no small chitinous plate adjacent to brush.

Habits.—Most of the species inhabit temporary ground-pools and are single-brooded; the eggs are laid singly, often on dry ground from which they may be washed into hollows by rain or melting snow. Some species are specially associated with salt-marshes either on coasts or in inland salt areas; these may have several broods annually, and the adults not infrequently have migratory habits. Breeding in tree-holes or rock-pools is exceptional in this subgenus, but occurs in a few species.

Classification and Distribution.—The numerous species of this subgenus can be arranged in a number of rather well-marked groups, which are for the most part characteristic of definite geographical areas.

Group A (*taeniorhynchus* group: *Culicelsa*). Differs from all the other groups in having no definite apical lobe to the male coxite, and the claspette appendage straight and bristle-like, instead of curved and more or less flattened. Lower mesepimeral bristles usually absent. Tarsi (at least of hind legs) with basal white rings on all segments (except perhaps the fifth). Most of the species in this group breed in brackish coastal swamps, and are found chiefly in America and Australia, one species being East African.

Aëdes (Ochlerotatus) vigilax Skuse.

Proc. Linn. Soc. N. S. Wales, XIII, 1889, 1731; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934.

♀.—Head clothed with scattered pale narrow-curved and black upright forked scales; antennæ dark brown, torus dark, base of first flagellar segment pale; palpi covered with black narrow-curved scales, white at apex; slightly more than the basal half of proboscis yellowish-orange, apical half black.

Thorax covered with brown narrow-curved scales; scutellum clothed with dark brown and bronzy narrow-curved scales; pleuræ covered with patches of white flat scales.

Abdomen covered with dusky-brown scales with white basal banding and lateral median white spots; venter black with scattered white scales.

Wings with veins covered with black scales and scattered white ones particularly on the anterior half; cross-vein 4–5 about its own length from cross-vein 3–4.

Legs black, femora pale at the base and on ventral surface, knee-spot distinct on all legs, tibiæ black above with white scales beneath; first tarsals basally banded white, conspicuous on hind legs, second and third tarsals of the fore and mid legs with narrow white basal bands, tarsi two to five with conspicuous white basal banding.

♂.—Palpi black, last two segments with pale basal bands; terminalia with basal lobe large, round and covered with numerous hairs; claspette small, with a simple straight apical bristle.

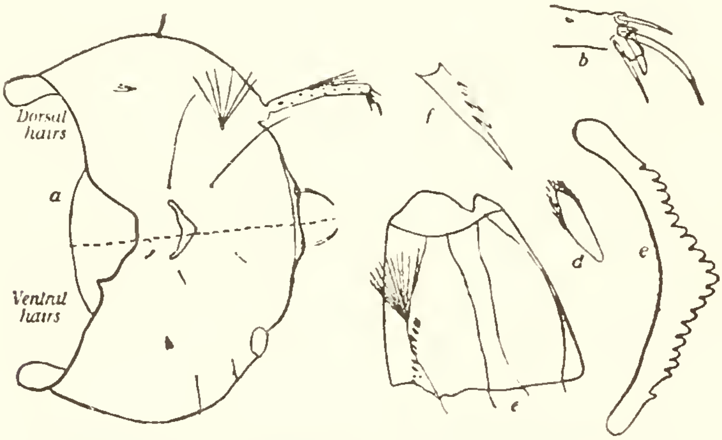


Fig. 25.—Larva of *Aëdes* (*Ochlerotatus*) *vigilax* Skuse. *a*, cephalic hairs; *b*, tip of antenna enlarged; *c*, mental plate; *d*, scale from 8th segment; *e*, siphon; *f*, spine on siphon. *After* Brug.

Larva.—Antenna (Fig. 25*a*, *b*): Length of the shaft about half the length of the head; constricted at the base; provided with minute spines; apex with one large and two smaller spines, the tip of the former being dark-coloured. A trifurcated hair inserted just below the middle and nearly half as long as the antenna.

Cephalic hairs (Fig. 25*a*): The tip of the preclypeal spinose hair is dark-coloured. Lateral and posterior frontal hairs long, simple; medial one absent. Near the base of the antenna one

large dorsal six-branched hair and ventrally a small bifurcate one. Two small occipital hairs on each side, two- and three-branched. Mental hairs small, foremost and mid ones simple, hindmost trifurcate. One small four-branched genal hair and a larger simple one.

Mental plate (Fig. 25*c*) very narrow, with twenty obtuse teeth, the two outermost ones small and sharper.

Scales on the eighth segment (Fig. 25*d*) about twenty on each side, in three rows; point obtuse, fringe fairly conspicuous.

Siphon (Fig. 25*e*) as long as broad, with a row of ten spines, the apical one the largest and quadriserrate (Fig. 25*f*), the pecten extending for not quite half the length of the siphon, and a many-branched barbed hair at nearly the middle.

Distribution.—Australia along the coastal belt and for some distance inland. (It has been taken at Longreach, Queensland, about 380 miles inland). Papua; Territory of New Guinea. Also found beyond the Australian region.

Bionomics.—This mosquito breeds in fresh and brackish water swamps for the most part and occasionally in salt water. This species has been called, incorrectly, a " salt water breeding mosquito ". It is a fierce biting mosquito, particularly in the late afternoon.

Relation to Disease.—A relatively poor intermediary host of *Wuchereria bancrofti*.

Through an unfortunate accident my slides of the larva and pupa were destroyed. The description of the larva is from Brug (1924).

Subgenus *Finlaya* Theobald.

Mon. Culicidæ, III, 1903, 281.

Characters.—Ornamentation very varied, some species being highly ornamented and resembling species of the subgenus *Stegomyia*, others much less ornamented and similar to species of *Ochlerotatus*. Scales of vertex, pronotal lobes and scutellum variable, in some species narrow and curved, in others broad and flat, all intermediate conditions occurring. Proboscis usually longer than front femora. Palpi of ♂ usually slightly shorter than proboscis, rarely equalling proboscis in length, in a few species (*eatoni*, *togoi*, etc.) only about half as long; last two segments usually more or less swollen and hairy, but sometimes quite slender and bare. Palpi of ♀ usually about one-fifth or one-sixth as long as proboscis, but sometimes longer (in *A. fulgens* more than half as long). Antennæ of ♂ with the plume-hairs directed mostly dorsally and ventrally. Anterior claws toothed in both sexes, in ♂ the larger claws usually with two teeth; hind claws usually simple. No lower mesepimeral bristles. Eighth segment of ♀ abdomen rather large, only slightly retractile, normally somewhat compressed laterally; sternite large and prominent; cerci always short. Hypopygium: Coxite long, without apical lobe and with at most a feebly developed basal lobe. Claspettes well developed, stem of moderate length and appendage nearly always long and slightly flattened (in *A. dissimilis* the stem is very short and the appendage reduced to a bristle). In a few quite unrelated species (*kochi*, *niveus*, *pulchriventer*, *leucocelænus*) a row or tuft of very large scales

is developed on the inner face of the coxite. Style simple, with long terminal spine. Paraprocts sometimes with two or three apical teeth. Phallosome always simple and undivided.

Larva.—Antennæ usually smooth, rarely more or less spicular; shaft-hair usually either single or bifid. Frontal hair *B* in front of *C*, usually single. Chaetotaxy of thorax and abdomen very variable in different species: sometimes strong spines are developed on dorsal surface of thorax. Siphon usually short; tuft near middle; pecten without detached teeth apically; acus usually present. Comb teeth either in a single regular row (*kochi*, *geniculatus*, etc.) or in a triangular patch. Ventral brush distinct, but seldom large; sometimes a small triangular chitinous plate is present on each side of brush.

Habits.—Most of the species breed in small collections of water such as occur in tree-holes, bamboo-stems, leaf-bases of various plants, or pot-holes in stream beds. Usually each species is more or less confined to one type of habitat, and therefore most are local in distribution.

Classification and Distribution.—In spite of the great diversity of ornamentation in this subgenus, it is not easy to find clearly-marked distinctions between the various groups of species; a few groups however are moderately well defined both in regard to their ornamentation and the areas in which they occur. The subgenus is almost cosmopolitan, being absent only from southern South America and perhaps Madagascar; it attains its greatest development in the oriental region.

Group A (*kochi* group: *Finlaya* s. str.). This group is clearly marked off from the others by having spotted wings and numerous light spots and rings on the femora and tibiæ. Scales of vertex almost all broad and flat, also those of posterior pronotal lobes and scutellum. Tarsal segments with basal white rings. Sternites tufted. Austro-Malayan region.

1. Hind tarsi with white rings at the tips of the first three segments, those on the second and third segments occupying about as much space as the black basal part; fourth segment all black, fifth all white 2
   Hind tarsi more extensively pale, the second and third segments having only narrow black rings at the base 4
2. General colour black, markings pure white; all the veins with numerous shall white dots; sternites 5–7 in ♀ with outstanding scales .. .. *poicilia* Theo.
   General colour lighter; wing-markings very variable, but the light areas either not dot-like or else much less numerous 3
3. Sternites 5–7 of ♀ abdomen with outstanding black scales; pale markings of wings and legs with little or no yellow tinge *kochi* Dön.
   No outstanding scales at end of sternite 5, though they are present on 6 and 7; pale markings of wings, femora and tibiæ more or less strongly tinged with yellow .. .. .. *samoana* Grünb.

Aëdes (*Finlaya*) *kochi* Dönitz.

Insekten Borse, V, 1901, 38; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 17; *Proc. Linn. Soc. N. S. Wales*, LIX, 1934, 233.

♀.—Head with narrow-curved scales on the vertex and nape, flat scaled elsewhere, scales dark brown on occiput, a small black patch on each side; proboscis short, brown with a broad white band in the middle; palpi short, brown, white at apex; antennæ brown, tori paler.

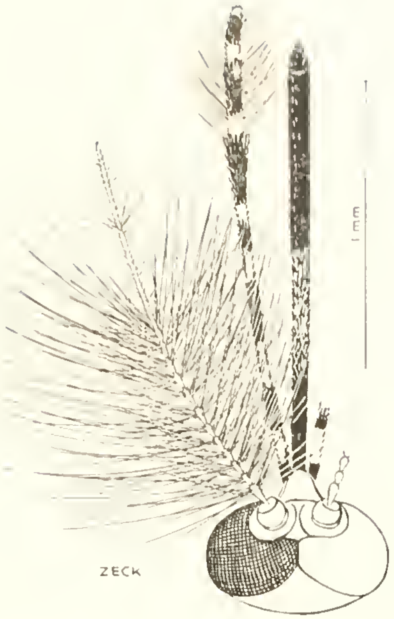


Fig. 26.—*Aëdes (Finlaya) kochi* Dönitz. ♂ head.

Thorax clothed with small, narrow-curved scales, bronze-coloured but with two patches of silvery-grey scales meeting in the middle line, numerous broad silvery scales in front of the scutellum, latter clothed with small flat, greyish scales; pleuræ clothed with patches of flat whitish scales.

Fig. 27.—*Aëdes (Finlaya) kochi* Dönitz. Wing.

Wings (Fig. 27) with the veins clothed with broad, short, dark and pale scales, giving the wing a mottled appearance.

Legs: Dark chocolate-brown, femora with about six equidistant white bands, tibiæ with about eight white bands, first tarsus with apical, basal and median white bands, second and third tarsals with apical and basal white bands, fourth not ornamented, fifth entirely white.

Abdomen: Dark chocolate-brown, segments I–VI with irregularly placed patches of white scales, VII without ornamentation; sternites apparently dark chocolate-brown with a median, broad stripe of white scales on the apical part of segments V–VII.

♂.—Palpi as figured; the white band on the proboscis is much narrower than in the ♀. Terminalia: Coxite rather broad, not narrowed distally, a large patch of hairs basally,

among which is a large bent and twisted bristle; on inner side beyond middle another small patch of short hairs, four or five longer, flattened bristly hairs or narrow scales toward the sternal side and near the above small patch; style about the length of coxite, slightly curved beyond middle, terminal appendage very long, with a long hair close to apex.

Distribution.—Widely distributed in north Queensland; Northern Territory; Territory of New Guinea; Papua.

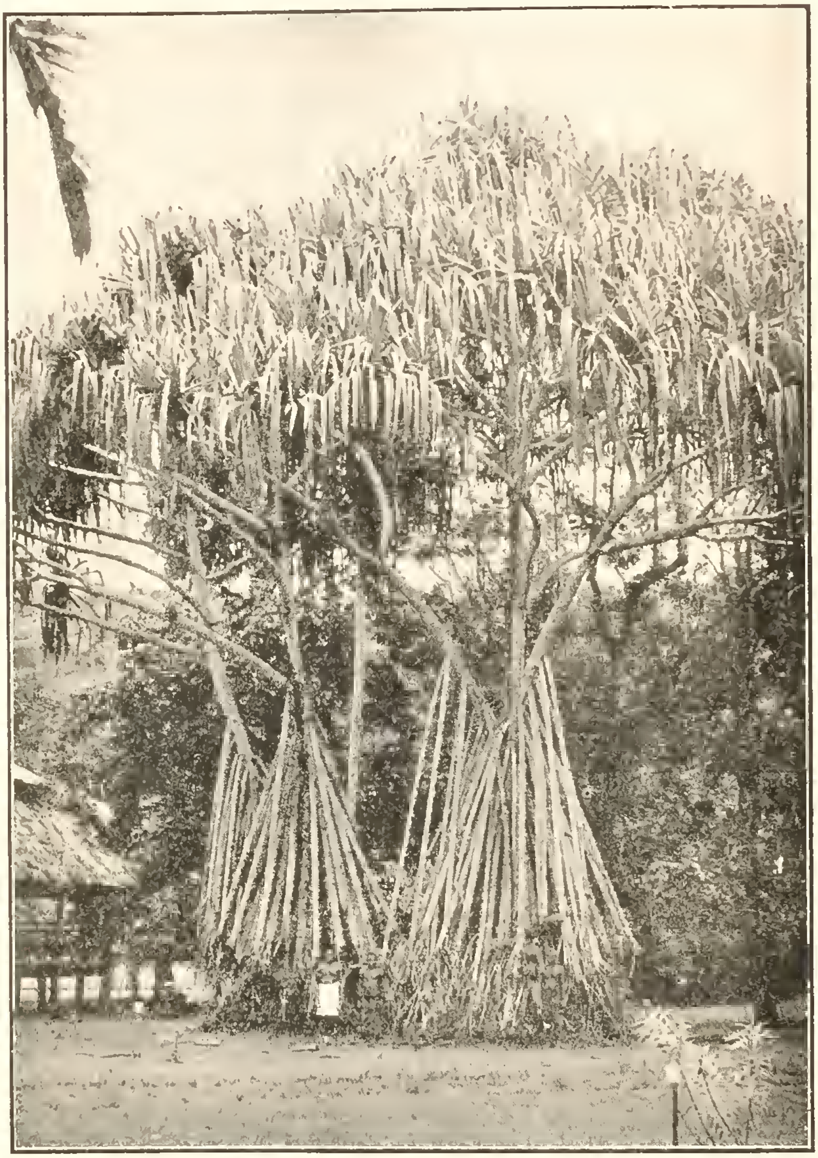


Fig. 28.—*Pandanus* sp. *Aëdes* (*Finlaya*) *kochi* Dönitz breeds in water held in the axils of the leaves of *Pandanus*.

Bionomics.—This mosquito breeds chiefly in the leaf axils of taro (*Colocasia* sp.), *Pandanus* sp. Other species of *Finlaya* breed in rot holes of trees and small rock pools. I have bred many thousands of mosquitoes from larvæ taken from coconut shells among which was not a single specimen of *Finlaya kochi*. The female is a most persistent biter during the day and night.

Relation to Disease.—An efficient intermediary host of *Wuchereria bancrofti*.

I have given Edwards' key to the typical form and its two varieties. Variety *poicilia* has so far not been found in the Australian region. The records to it all refer to *Finlaya kochi.*

Subgenus *Stegomyia* Theobald.

Mon. Cul., I, 1901, 283. Type *fasciata* Fab.

"*Characters.*—Ornate species, usually blackish with white markings on thorax and legs. Scales on vertex, anterior pronotal lobes and scutellum mostly or all broad and flat. Width of front variable, the eyes in some species practically touching, in others well separated. Proboscis in both sexes only about as long as front femora. Palpi of ♂ (Fig. 35) as long as proboscis or not much shorter, distinctly 3-segmented, last two segments slender, upturned and almost bare. Antennæ of ♂ with the plume-hairs directed mainly dorsally and ventrally. Lower mesepimeral bristles absent (except in *A. vittatus*). Larger claw of front and middle legs of ♂ often simple, sometimes also the smaller claw. Front and middle claws of ♀ usually toothed (simple in *albopictus* and related species); hind claws usually simple in both sexes. Eighth segment of ♀ abdomen partially retractile, sternite not very large; cerci usually quite short. Hypopygium: Coxite without apical lobe; basal lobe (plaque) present and hairy; no claspettes. Style nearly always simple, with terminal or subterminal spine (spine near middle in *albolineatus*). Phallosome (Fig. 36) divided into two lateral plates, each of which bears numerous teeth externally.

"*Larva.*—Antennæ usually smooth, with small simple hair on shaft, and rather short. Frontal hairs B and C placed one in front of the other. Meso- and metapleural plates usually carrying a spine. Comb-teeth usually in a single regular row. Siphon short, index usually well under 2; pecten without detached teeth apically; tuft well before tip of siphon; no acus. Anal saddle usually rather small. Ventral brush of anal segment often much reduced.

"*Habits.*—Most of the species are day-flying insects; most breed in tree-holes, leaf-bases, coconut-shells or other small collections of water, but *A. ægypti* is seldom found except in association with man, breeding in a variety of small artificial receptacles about houses. *A. vittatus* is the only species (so far as known) which breeds in small puddles in rocks, and is thus somewhat aberrant in habits as well as in structure" (Edwards, 1932).

For an account of the specific breeding places of *Aëdes* (*Stegomyia*) *ægypti* and *Aëdes* (*Stegomyia*) *albopictus*, see under Control, p. 92.

The species name *ægypti* (1762) has come into scientific usage in preference to that of *fasciatus* (1805) because it is the first published name, so far as we know, of the mosquito under discussion. This mosquito has also gone under the following names, among others, in the literature: *argenteus* (1787) and *calopus* (1818). It is laid down that the earliest published scientific name, accompanied by a description or figure, of an animal or plant, is the name under which an animal or plant is to be known.

For clarity and accuracy the intermediary hosts of dengue fever have been referred to throughout as *Aëdes* (*Stegomyia*) *ægypti* and *Aëdes* (*Stegomyia*) *albopictus* and not as *Aëdes ægypti* and *Aëdes albopictus* respectively.

A table is appended below for the separation of the species dealt with in this publication.

1. Mesonotum with one median white stripe .. *albopictus* (Skuse)
   Mesonotum with lyre-shaped pattern on lateral margins .. 2
2. Proboscis concolourous .. .. *ægypti* (Linn.)
   Proboscis with a conspicuous white band .. .. *Finlaya notoscriptus* (Skuse)

Aëdes (*Stegomyia*) *ægypti* Linnæus.

Hasselquist's Reise nach Palestina, 1762, 470 (*Culex*); Taylor, Service Publication (School of Public Health and Tropical Medicine) No. 1, 1934.

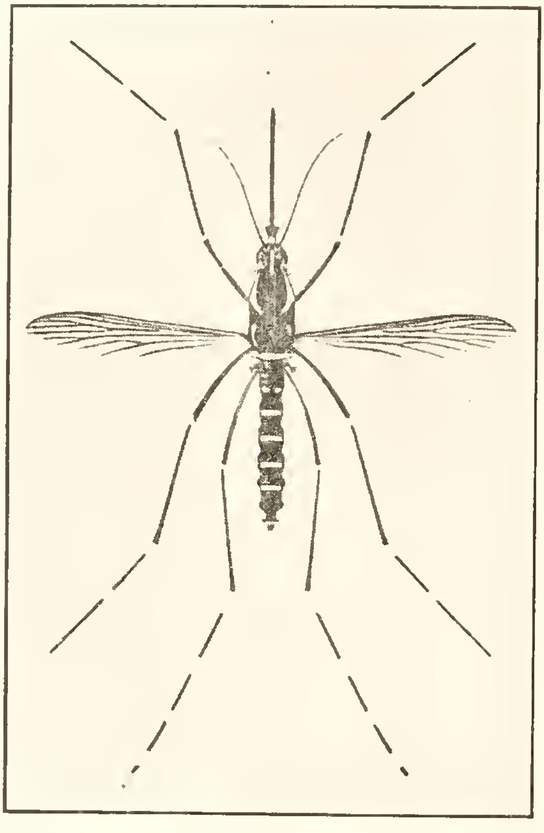


Fig. 37.—*Aëdes* (*Stegomyia*) *ægypti* Linnæus.

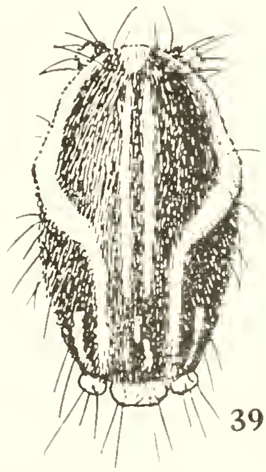
♂, ♀.—Head (Fig. 38): Occiput covered with blackish brown flat scales, flat white ones laterally and bordering the eyes and in the centre, the latter forming a straight line with those on the prothorax; brown hairs overhanging the eyes; proboscis black; base of antennæ, clypeus and apical part of palpi (♀) covered with silvery-white scales, white bands on ♂ palpi as illustrated; clypeus in ♂ usually bare, white scales, if present, are few in number.

Thorax (Fig. 39): Covered with brown narrow-curved scales, ornamentation as illustrated, prothoracic lobes and

scutellum densely covered with silvery-white flat scales, posterior half of mid lobe with flat, brown scales; pleuræ with numerous patches of silvery-white scales.

Abdomen: First and apical segments covered with white flat scales; seventh not banded, but with moderately large sub-basal white spot on each side, segments two to six inclusive with white basal banding, otherwise segments clothed with blackish-brown imbricate scales, segments one to six inclusive with lateral silvery-white sub-basal spots, venter white scaled. There are specimens in the School Collection with the abdominal scaling almost completely fawn in colour. Terminalia (Fig. 40). ♂: Tergite with two large conical lobes separated by a deep V-shaped emargination, each lobe with a few short hairs; style somewhat widened in middle, with a slender, short terminal spine: paraprocts with a ventral arm which is not much shorter than the main portion; phallosome with fine teeth only. "♀: Eighth segment largely retractile, somewhat compressed, its sternite with sides produced into conspicuous rounded flaps, the inner walls of which are sclerotized; ninth tergite shield-shaped, shorter than cerci, with wide and deep posterior emargination; insula longer than broad and bare; cerci broad and not very long, scaly; post-genital plate with rather shallow notch" (Edwards, 1941).

38



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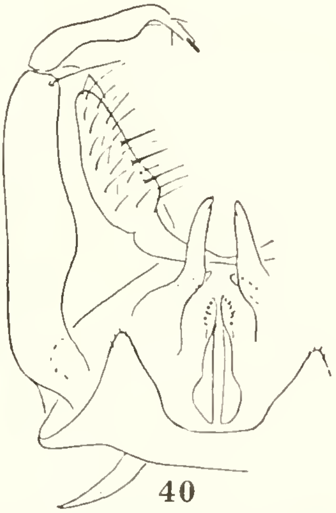

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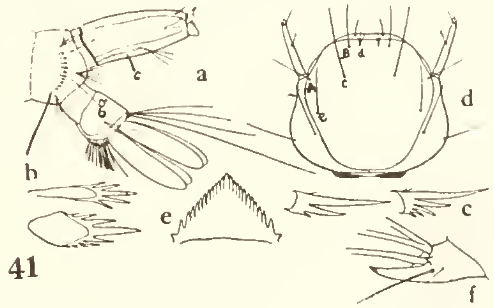
Fig. 38.—Head of *Aëdes* (*Stegomyia*) *ægypti* to show markings of ♂ palpi. Fig. 39.—Thorax of same to show markings. Fig. 40.—Terminalia of *Aëdes* (*Stegomyia*) *ægypti*.

Wings: With the veins covered with black scales; bases of the first sub-marginal and second posterior cells about level, *m-cu* about its own length from *r-m*, sixth vein ending well beyond base of fork of five.

Legs: Black, fore and mid femora with a white line on anterior surface from base to near apex; hind femora with a similar white line on apical half, basal half of anterior surface all white; apices of all femora with a small silvery-white spot; tibiæ black: fore and mid tarsi with white basal banding on first and second segments; hind tarsi with broad white basal

banding on segments one to four inclusive, fifth white; this segment is subject to variation in marking—specimens are to be found which have a black basal band of varying width.

"*Larva* (Fig. 41): Head rounded, wider than long (*d*); antennæ slightly curved, cylindrical, smooth, a single small hair in the middle, a long hair, a spine and a small digit at apex. Mental plate (*e*) rounded triangular, central tooth large, with thirteen on either side, subequal, the outer ones the larger. Sub-ventral processes (*f*) on lateral margin of thorax. S.p.ii each process with a long stout spine and numerous smaller ones at its base. S.p.iii a large stout spine with two smaller ones at its base. Syphon stout, short, less than twice as long as broad; pecten (*c*) with about fourteen teeth, running about half the length of syphon, followed by a single tuft of three hairs; single pecten tooth a rather long spine with smaller teeth at its base. Lateral comb (*b*) on eighth segment of about 8–11 teeth in a single row, each is elongate, with a long apical spine and curved stout ones more basally, decreasing in length. Anal segment not quite so long as broad; plate (*g*) not completely enveloping it; dorsal tuft (*d.h.*) composed of two long hairs and a shorter one on either side; lateral hair almost as long as segment, double; ventral brush (*v.b.*) moderately dense and long; anal papillæ long, apices rounded.



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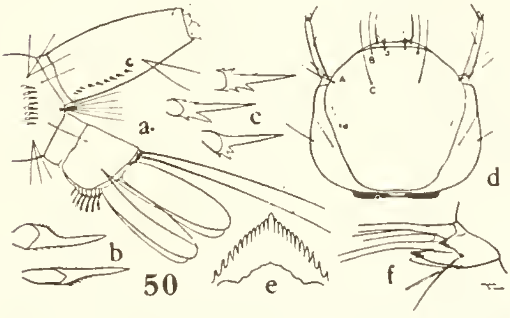

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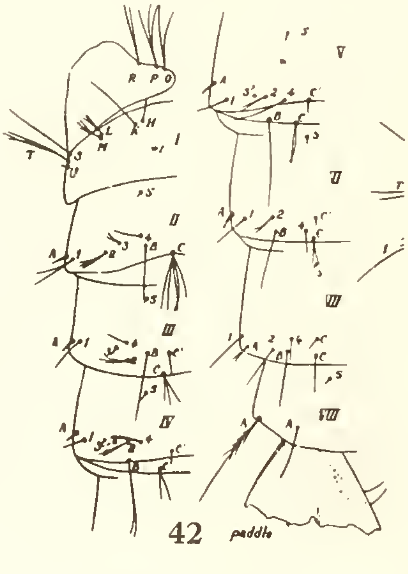

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Fig. 41.—*a*, apex of abdomen of larva of *Aëdes* (*Stegomyia*) *ægypti*; *b*, comb teeth; *c*, pecten teeth on syphon; *g*, saddle of anal segment; *d*, head showing head hairs; *e*, mentum; *f*, base of metathoracic pleural hairs.
Fig. 42.—Abdominal chætotaxy of pupa of *Aëdes* (*Stegomyia*) *albopictus*.
Fig. 50.—Apex of abdomen of larva of *Aëdes* (*Stegomyia*) *albopictus*, lettering as in Fig. 41.

"*Pupa* (Fig. 42).—Dorsal thoracic seta very short (much shorter than supra-alar), usually double but sometimes single or triple. P markedly longer than O or R. Abdomen:—I: H, K, S and T all subequal in length and single (an unusual condition); K at most one-half longer than H and very little stouter. II: C short usually double or triple, occasionally single. III: C short, usually double, placed obliquely internal

to B (not behind it). II-VI: A rather spine-like, well marked even on II and progressively longer on III-V, but no longer on VI than on V; B single, not more than half as long as segments. VII: A single and strong, much longer than A-VI, other setæ all short and single. VIII: A with 2–5 sub-plumose branches, reaching about to middle of paddle. Paddles oval, about 1·3 × 1, with strong denticles on distal margin; seta single about one-fourth length of paddle" (Edwards, 1941).

Variation.—*Aëdes* (*Stegomyia*) *ægypti* Linn. is subject to much individual variation. This has been studied by Summers-Connal (1927) especially in regard to the variation in abdominal and hind tarsal markings. "She found that in the Lagos district the dorsal surface of the abdomen may be entirely black or almost entirely white, with various intermediate proportionate quantities of dark and light scales; the white bands on the tergites may be narrower or broader, and situated either on the basal or apical margins, or both. The amount of black at the tip of the fourth hind tarsal segment varies, as do the proportionate lengths of the fourth and fifth segments. Similar variations have been noted in other districts.

"Another form of variation is seen in the colour of the thoracic integument and of the darker scales of the mesonotum, which are normally black (or nearly so), but may be brown, even of quite a light tint. Brown specimens appear to be associated especially with dry country or with coastal districts. Such light brown specimens were found by Drake-Brockman in the coast towns of British Somaliland, while D. J. Lewis writes (1939) that 'in many specimens from Port Sudan, Suakin and Tokar the usual black scales are replaced by brown or yellow ones on various parts of the body, especially the mesonotum and parts of the abdomen and femora and vertex'; and again (April, 1940), 'I have had a cage colony of the pale *Aëdes ægypti* from Port Sudan breeding here for eight months now and the pale colour still persists'. Somewhat similar brown specimens found near Brisbane (Queensland) by Bancroft were given the varietal name *queenslandensis* by Theobald.

"There is little evidence that distinct local or biological races of *A. ægypti* exist unless the varieties *queenslandensis* (noted above) and *atritarsis* are such. Mathis (1934) reared strains from Greece, Cuba, Java and West Africa under identical experimental conditions and found that their biology was similar" (Edwards, 1941).

I have repeatedly found that the variation of markings is very common and that fawn-coloured specimens, or largely so, will produce normally marked specimens or that one may have, in the same batch, normal specimens and others with normal thoracic markings, but the abdomen almost entirely clothed with fawn scales or the clothing of the thorax and abdomen may be mainly of fawn-coloured scales.

"*Hybridization.*—The recent studies of Toumanoff (1937) on the experimental hybridization of this species and *A. albopictus* have already been noted. A remarkable feature of these experiments was that all the offspring of a cross closely resembled the female parent, at least in ornamentation; in the cross

ægypti ♂ × *albopictus* ♀ (which was easily obtained) all the many hundreds of offspring of the first and subsequent generations were precisely like *albopictus*, whereas in the reverse cross (which was only obtained once) they were like *ægypti*. Unfortunately no details were given of the morphological characters of the hybrids; it would be of particular interest to ascertain whether the male terminalia of the hybrids showed intermediate structure, and if not whether they resembled those of the male parent or those of the male corresponding with the female parent.

Relation to Disease.—An efficient intermediary host of dengue and yellow fevers. It appears to be quite inefficient in regard to filariasis.

Feeding and other Habits.

"*A. ægypti* is almost purely domestic and in feeding shows a preference for human blood, though in the laboratory it will also feed on dogs, goats, bandicoots, rats, rabbits, guinea-pigs or canaries (Bacot, 1916, and others), or even, in the absence of warm-blooded animals, on frogs or turtles (Woke, 1937). According to Marchoux (quoted by Kazeef, 1935) it prefers to bite children rather than adults and Europeans rather than Africans. Bacot in West Africa concluded that 'in captivity there seems to be no regular precedence of either pairing or feeding; both functions are practised at any hour of the day or night—late afternoon being perhaps the most favoured'; he also found that the first meal is taken 1–2 days after emergence and subsequent meals at about 3-day intervals. Flu (1928) in Surinam and Cardamitis (1929) in Greece independently stated that whereas the first blood-meal is always taken by day, later meals are taken only at or at least mainly at night; if correct this is important in view of the fact that the mosquito can only become infective after a meal. Daytime biting is performed in a rather dim light. Dark surfaces are preferred to light ones; Brett (1938) showed that *ægypti* has a definite preference for settling on dark or red cloth, and that light (especially yellow) and blue cloths are much less attractive or even repellent. A perspiring skin attracts more readily than a dry one.

"According to Hopkins *ægypti* though occurring in the houses of Europeans is not found in native huts in Kampala; he considers that this is due to the huts being too dark. This may partly explain the supposed preference of the mosquito for feeding on Europeans. Wanson (1936) in the Congo found that adult *ægypti* used crab-holes as day-time resting-places, although this species did not breed in such places" (Edwards, 1941).

Notwithstanding the opinion held by many workers, my experience has been that this mosquito will bite at all hours of the day and night. This I have recently confirmed at Cairns, Queensland, when *Aëdes* (*Stegomyia*) *ægypti* adults were abundant in June-July, 1942, and equally annoying in their attentions by night as in the day time. Some, at least, of the specimens biting by night were old, judging by their damaged wings and the partly abraded thorax, but others were perfect specimens in regard to the details of scaling, etc.

Egg-laying.

Aëdes (*Stegomyia*) *ægypti* both in the breeding cage and in the "wild" state appears to invariably lay its eggs between sunset and sunrise. The eggs are deposited, for preference, on a damp surface rather than on water. The egg is cigar-shaped, black, and possesses a pattern as shown in Fig. 31

"Bacot (1916) found that at least one meal of blood is essential for the production of fertile eggs, and normally the eggs are ripened in batches, the females feeding after each oviposition. These observations have been confirmed, but much variation has been found to occur in the number of eggs laid and in the size of the batches. Bacot mentions females laying 712 and 837 eggs in 15 and 22 batches respectively; Mathis (1935) at Dakar obtained from each of seven females an average total of 13,600 eggs in 22 batches after 22 blood-meals extending over 87 days; Shannon and Putnam (1934) give a mean maximum of eggs per female of only 350. Eggs can survive several months' desiccation, but in spite of this they are laid only on wet surfaces, and the females will die rather than oviposit on dry surfaces. Fertile eggs may be laid some weeks after the removal of males from a breeding-cage.

Length of Life.

"Adults of both sexes of *A. ægypti* can live for several weeks or months, but females are more long-lived than males, and both sexes live much longer in a moist atmosphere even when well provided with food. Beeuwkes and others (1933) found that at Yaba, Southern Nigeria, the length of life for males was 40–61 days and for females 70–116 days; at Gadan, Northern Nigeria, where the climate is drier, the figures were 10–43 and 22–65 days respectively; length of life was increased by keeping the insects in an artificially moist chamber. Shannon and Putnam (1934) in Brazil give a mean life of 62 days for females fed on blood and of 82 days for those fed on honey. Adults probably cannot survive a dry season" (Edwards, 1941).

I have kept adult females of the *same* batch alive for 90 days with regular blood meals in a breeding cage at room temperature in Sydney from the end of September onwards. The mosquitoes were well supplied with moisture and, in addition, there was a supply of dates or sultanas for them to feed on. All the males were dead at the end of two months.

"The average length of life, under natural conditions, is probably not more than six weeks" (Siler, Hall and Hitchens, 1926).

"*Range of Flight.*—Although the normal range of flight of *ægypti* is thought not to exceed 200 yards, Shannon and Davis (1930) showed that it may extend to 1,000 yards or more, marked specimens released on a ship moored at this distance from shore having been recovered on land" (Edwards, 1941).

Distribution in Australia.

This mosquito was known to be established in New South Wales north of a line connecting the towns of Newcastle and Bourke (Ferguson, 1928). Since 1930 (Fig. 13, Map) I have

carried out a number of surveys in New South Wales in an endeavour to establish its most southerly distribution. I found it in March, 1931, at Brooklyn (Hawkesbury River Railway Station), Rookwood Cemetery (22.v.42), both places being in the County of Cumberland and the latter situated in a suburb of Sydney; Merriwagga (12.ii.36), Narrandera and Junee also in February, 1936. The latter are at present, as far as is known, the farthest south that this mosquito has penetrated in New South Wales.* Its abundance in the towns of Temora and Gulgong is very striking, demonstrating that this mosquito has been established in these towns for many years; one was tormented from early morning until late at night whenever one sat down even for a moment.

The map shows the towns which have been found by me to be infested with *Aëdes (Stegomyia) ægypti*. It will be noted that many names of towns are omitted from the map. They were not visited since, having found this mosquito in near by towns, it would have been a waste of public money and time to have searched these intervening localities for it. It may be taken as a fact that towns to the east, north and west and possibly to the south of Junee and Narrandera are infested, to a greater or less degree, with *Aëdes (Stegomyia) ægypti*.

Mackerras (1926) states that *Aëdes (Stegomyia) ægypti* (referred to specifically as *argenteus*) definitely does not occur in the district (Sydney). It may be remarked that it is impossible to say *definitely* that any particular insect is absent from a given area.

Dispersal by Human Agency.

It may be mentioned here that *Aëdes (Stegomyia) ægypti* is a born traveller. I have never travelled on a long-distance train in both northern New South Wales and in Queensland without finding adults of this mosquito. In the middle of the last century it was transported by the teamsters in their water barrels, later by motor car owners in their water bags when making long journeys, and now by the aeroplane.

Ferguson (1928) states that "the extension of this mosquito to Sydney is unlikely in view of the fact that it must have been introduced countless times already, but has never been able to establish itself. This failure to become established in Sydney is probably partly a *climatic limitation and partly due to the absence of suitable breeding grounds*. [The italics are mine—F.H.T.]

"On the other hand, in New South Wales, and probably in parts of southern Queensland, breeding of *Aëdes ægypti* L. is confined to the warmer months and stops during the winter, this season being passed in the egg stage."

I maintain that climate does not play a part in the distribution of this mosquito in New South Wales: Breadalbane (2,283 ft. altitude), which has experienced snow in mid-summer, is infested with this mosquito. There is also no lack, and never has there been, of suitable breeding places in the metropolitan area of Sydney.

The late Dr. Ferguson when he wrote the above quoted paragraphs did not appreciate the habits of this mosquito

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* Theobald recorded this species (*Monogr. Culic.*, I, 1901, 293) from Victoria in error.

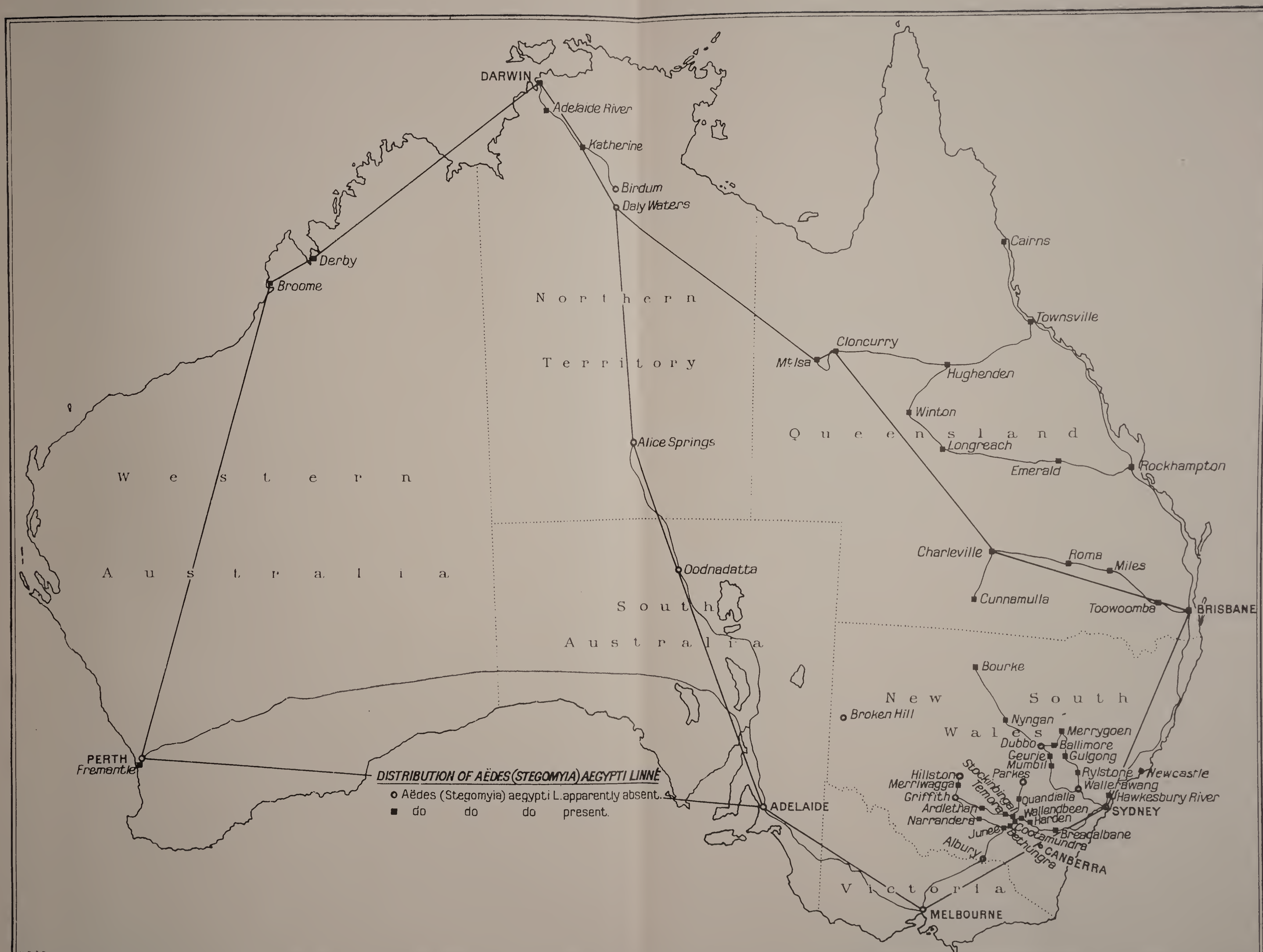
DISTRIBUTION OF AËDES (STEGOMYIA) AEGYPTI LINNÉ
Aëdes (Stegomyia) aegypti L. apparently absent.
do do do present.
DARWIN
Adelaide River
Katherine
Birdum
Daly Waters
Derby
Broome
Northern Territory
Alice Springs
Western Australia
Oodnadatta
South Australia
PERTH
Fremantle
ADELAIDE
MELBOURNE
Victoria
Cairns
Townsville
Cloncurry
Mt Isa
Hughenden
Winton
Queensland
Longreach
Emerald
Rockhampton
Charleville
Roma
Miles
Cunnamulla
Toowoomba
BRISBANE
Bourke
New South Wales
Broken Hill
Nyngan
Merrygoen
Dubbo
Ballimore
Geurie
Gulgong
Mumbil
Parkes
Rylstone
Newcastle
Hillston
Merriwagga
Stockinbingal
Temora
Wallerawang
Griffith
Quandialla
Hawkesbury River
Ardlethan
Wallendbeen
SYDNEY
Narrandera
Harden
Junee
Cootamundra
Breadalbane
Albury
Bethungra
CANBERRA

Fig. 43.

because (1) it will be seen from the map indicating the present distribution of *Aëdes* (*Stegomyia*) *ægypti* that it has extended as far south as Junee and Narrandera. It has been found by me at Rookwood Cemetery (22.v.12), which is in the metropolitan area of Sydney. Moreover, there are many more areas of Sydney where there are suitable breeding grounds and possibly it is in these areas undetected; and (2) breeding of *Aëdes* (*Stegomyia*) *ægypti* does not stop in mid-winter (June-July), since I have found the larvæ of this mosquito in "fire-buckets" (Fig. 44) on a railway station (Ourimbah) in this State at this period of the year. The larvæ were definitely active and not hibernating. I do not believe that insects hibernate in Australia except perhaps in the snow belt of Mount Kosciusko and Mount Buffalo.

Hamlyn Harris (1931) states: "*A. argenteus* is making steady inroads into all the inland towns of Queensland, and most assiduously follows the railway lines . . ."

It is not clear upon what basis the above statement was made by Hamlyn Harris. It has long been known that *Aëdes* (*Stegomyia*) *ægypti* has been present in the far western towns of Queensland before the year 1900. There are specimens of this mosquito in the Queensland Museum taken by Wild at Cunnamulla, south-western Queensland, in 1881. The introduction of this mosquito into Australia dates back, probably, to the days when the Malays visited our northern shores in their sea-going prahus, from which time it is possible that dengue fever was also introduced.

Aëdes (*Stegomyia*) *albopictus* Skuse.

Indian Museum Notes, III, 1894, 20 (*Culex*).

A conspicuous species on account of the silvery-white line on the scutum, white scales on the pleura in irregular patches, the uppermost forming a line of dots just below the margin of the scutum.

♂, ♀.—Head (Figs. 35, 45): Occiput clothed with flat scales, a broad median silvery-white line from the nape to between the eyes of flat scales; a few upright-forked black scales present on the nape, lateral of the median white line the scales are brownish-black. Eye margins with small white scales and brownish-black bristles overhanging the eyes; there is a patch of silvery-white flat scales on each side of the head. Antennæ dark brown, plumes of ♂ brownish, base silvery-white scaled on inner surface; clypeus brown; proboscis dark brown; palpi with apical half of dorsum silvery-white scaled, and about one-fifth length of proboscis in ♀; palpi of ♂ black scaled about the apical segment longer than the proboscis, with four silvery-white patches—one at the base of the apical segment, one at the base of penultimate, and two on the antepenultimate segment.

Thorax (Fig. 46): Prothoracic lobes with a patch of broad, flat, silvery-white scales, scutum clothed with dark brown, narrow-curved scales, with a median silvery-white line of narrow-curved scales from the anterior margin toward the antescutellar area, tapering posteriorly; there are three short white lines on the scutum immediately in front of the scutellum, a

patch of mixed silvery-white scales over wing roots, scutellum clothed with silvery-white flat scales, mid lobe with a few brown flat ones on anterior margin, bristles on anterior margin dark brown, pleura with irregular patches of scales (Fig. 47).

Wings (Fig. 48): Scales uniformly brown on veins; base of first fork-cell about level with the base of the second, *m-cu* about three times its length from *r-m*.


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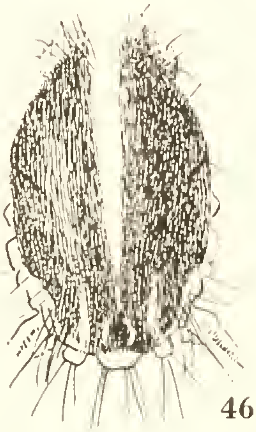
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47

Figs. 45, 46, 47.—*Aëdes* (*Stegomyia*) *albopictus*. Head; thorax to show dorsal markings; side of thorax to show markings (note that the uppermost row of white scales is broken up into spots).

Legs: Brownish-black, fore femora white scaled on basal half beneath; there is a more or less distinct line of white scales on the apical third, all femora with an apical silvery-white patch of scales, first and second tarsi with basal white patch, remaining tarsi brownish-black, mid femora beneath with basal half white, apical half brown scaled, tibia and tarsi brown, first and second tarsal segments with white basal spot; base of hind femora white scaled, basal two-thirds white scaled beneath, outer edge covered with pure white scales on basal two-thirds, a narrow silvery line reaching almost to the apex, dorsal surface brownish-black, tarsi i-iv with broad white basal bands, fifth tarsal white scaled.

Abdomen: Covered with dusky-brown scales, segments with somewhat obsolete basal bands, broadening laterally, seventh segment with a well defined, sub-basal, white spot on each side; venter clothed with brownish-black scales, with basal white bands on third and fourth segments, banding in the middle on segments five and six. There is a rather large basal white patch on segment one laterally, second segment white scaled, except a dark submedian apical spot, segment three has an apical median white spot. Terminalia of ♂ (Fig. 24 *a*, *b*): Sidepieces slightly more than twice as long as broad, basal lobe (*b.l.*) clothed with numerous moderately long hairs with bent apices, and five or six blade-like appendages with curved apices; style shorter than sidepiece, widened apically, latter with fine sparse hairs, spine close to apex; ninth tergite (*t.*9) with two slender hairy sublateral lobes, median portion strongly produced into a blunt process; mesosome (*m.*) consisting of two slender stems, apex broadened considerably, base slightly so, apex with about 10 long blunt teeth; tenth sternite (*s.*10) simple, with chitinized apices.

"*Larva* (Fig. 50): *Antenna:* Shaft about 10 times as long as wide, smooth, with single hair arising rather more than half-way from base. *Frontal hairs* all placed far forward, all fine and inconspicuous; A near base of antenna, with 2–3 fine branches; C internal and about level with A, usually single, fairly long; B single but fairly frayed, some distance from, but directly in front of C; *d* slightly anterior and internal to B, with a number of fine branches; *e* single, fine, and long. Lateral hairs of *thorax* of moderate length, of 1–3 branches, pleural tubercles with minute sharp thorn-like processes with several points. Fairly long lateral single or 2-branched and smaller 3-branched hairs on *abdomen*. Comb of 8–12 large strong teeth, without lateral denticles, in a single row, not arising from a chitinized plate. *Siphon* rather more than twice length of diameter at base. Pecten of 7–14 small teeth, with basal lateral denticles. Tuft of 2–3 branches at about middle of siphon, usually just beyond most apical pecten-tooth. *Anal segment* nearly enclosed in chitinous ring; a few minute spines on hind margin towards dorsum; *lh* of two long branches. Both *isc* and *osc* single and long, or inner may be split into two. Fan-hairs fairly long but not numerous (8–10), arising from small fan-plate; papillæ long, tips rounded" (Barraud, 1934).

Relation to Disease.—An efficient intermediary host of dengue. Results in regard to filariasis appear to be

48

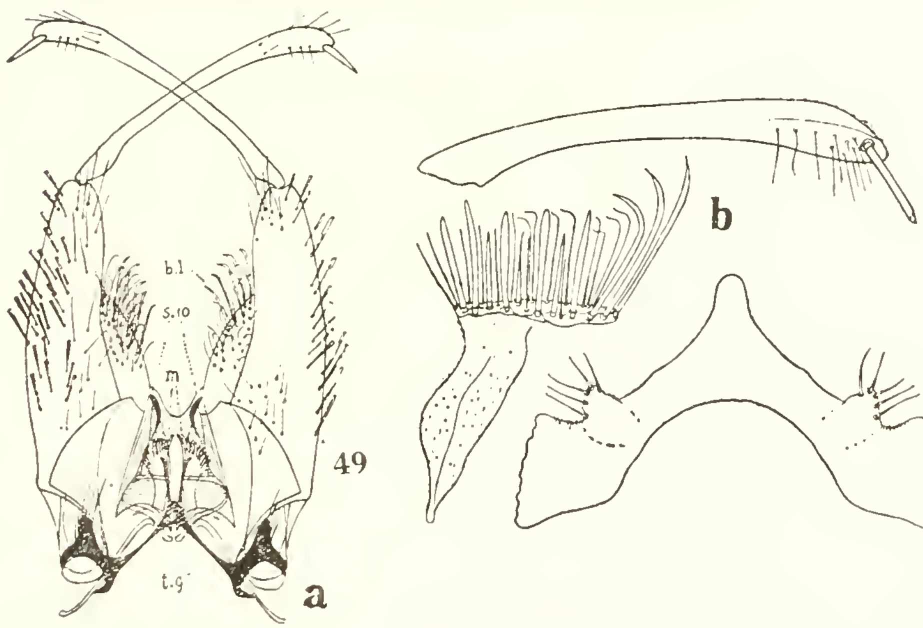

Fig. 48.—Wing of *Aëdes* (*Stegomyia*) *albopictus*. See footnote, p. 90. Fig. 49.—*a*, Terminalia of same; *b.l.*, basal lobe; *m*, mesosome; *s.*10, tenth sternite; *t.*9, ninth tergite. Fig. 49*b*.—Style, plaque and ninth tergite more highly magnified.

contradictory. Larvæ of *Wuchereria bancrofti* show, according to most authors, an incomplete development in this mosquito, the larvæ not reaching the proboscis. Flu (1921) states that *Wuchereria bancrofti* develops in *albopictus* as efficiently as in *Culex fatigans* and (1921*a*) declares that in Batavia *albopictus* belongs to the best intermediary hosts, next to *Culex fatigans*.

Belding (1942) states: "The virus is transmitted chiefly by *Aëdes ægypti*, but *Anopheles albopictus* and *Armigeres perturbans* have also been found to be vectors in the Orient." Presumably Belding means *Aëdes* (*Stegomyia*) *albopictus* and *Armigeres obturbans*. With regard to the latter species the evidence is, at present, purely presumptive that it may transmit the virus of dengue.

Distribution.

Northern Territory, Darwin. This mosquito has so far only been found at Darwin, but it enjoys a wide distribution outside Australia.*

Skuse described this species from three female specimens taken by E. C. Cotes, who informed him (Skuse) that the insect was a great nuisance in Calcutta. Skuse stated that the type was in the Australian Museum.

Breeding Places.

Common breeding places are bamboo stumps, tree holes, holes in stumps, and axils of leaves as well as house tanks. Larvæ have also been found in coconut shells. Larvæ have been found on rare occasions in ditches and pools (Liston and Akala, 1913, and James, Da Silva and Arndt, 1914), a rivulet, rock pool, etc. (Senior-White, 1920).

Egg-laying Habits.

It has been proved experimentally that somewhat decayed infusions of hay, wheat, oats, rice and potatoes are more attractive than pure water to the ovigerous female.

Aëdes (*Stegomyia*) *albopictus* is more commonly found in the open than indoors. It feeds in subdued light, biting by day as well as by night.

Control.

Aëdes (*Stegomyia*) *albopictus* selects similar breeding places to those of *Aëdes* (*Stegomyia*) *ægypti* and in addition it breeds in the bush away from habitations.

So far as the breeding places near houses are concerned, the same control measures as used against *Aëdes* (*Stegomyia*) *ægypti* will operate. Where this species is found breeding in rot holes, depressions, etc., in trees, sawdust impregnated with coal tar should be used. Coconut shells, disused tins and similar breeding places must be destroyed and then buried.

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* Mr. Musgrave, Entomologist, The Australian Museum, informs me that he has never seen the above type, so we must infer that it no longer exists. Since this was written Mr. Musgrave has found a slide labelled "Wing of Mosquito *Culex albopictus* Sk., Bengal, India". This slide can not, however, be the remnant of the type, since the label is in Skuse's handwriting. Fig. 48 is a photomicrograph of the above wing.

Aëdes (Finlaya) notoscriptus Skuse.

Proc. Linn. Soc. N. S. Wales, XIII, 1889, 1738 (*Culex*); Taylor, Check List of the Culicidae of the Australian Region, Service Publication (School of Public Health and Tropical Medicine) No. 1, 1934, 18.

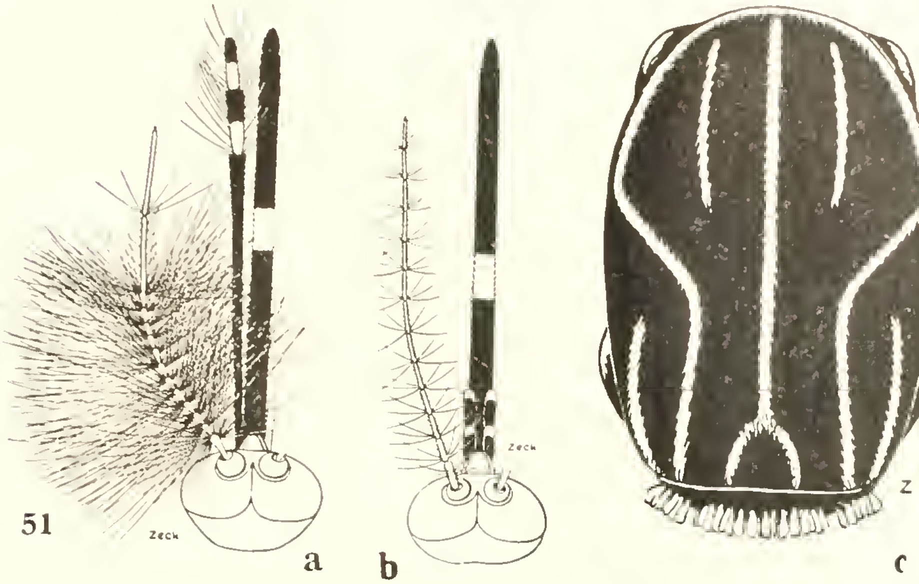


Fig. 51.—*a*, ♂ head; *b*, ♀ head; *c*, thorax of *Aëdes (Finlaya) notoscriptus.*

Illustrations of the male and female head and the thorax of this mosquito have been given, since, at a glance, it is possible to mistake it for *Aëdes (Stegomyia) ægypti*. It will be noted that there is a conspicuous white band on the proboscis, whereas the proboscis of *Aëdes (Stegomyia) ægypti* is unicolourous, the ornamentation of the male palpi is somewhat similar but readily distinguishable when examined with care. The thoracic markings are also somewhat similar but are distinct and characteristic of each species.

BIONOMICS.

Hatching of the Larva.

The larva generally hatches on the second day after the egg is laid. The eggs may be kept for several months if they are placed in a moist atmosphere for thirty-six to forty-eight hours before they are desiccated. This is important, for unless they be held in a moist atmosphere for the above period the embryo will not have developed sufficiently to prevent the collapse of the egg when it is subjected to desiccation, which will result in the total loss of the eggs. Eggs which have been desiccated will hatch within a few hours of being placed on water.

Larval and Pupal Period.

The time taken by the larva to become full-grown is usually about seven to ten days under optimum conditions of food and temperature. This time has extended to twenty days at room temperature in mid-winter in Sydney. On the other hand the life cycle from egg to adult may be completed in seven days.

The pupal period is usually two to three days, but under adverse conditions it may be prolonged.

Breeding Places.

There is only one species, *Aëdes* (*Stegomyia*) *vittatus*, which breeds in small rock pools. All the remaining species breed in tree-holes, leaf bases, coconut shells, or other similar collections of water, except *Aëdes* (*Stegomyia*) *ægypti*, which breeds in clean water in household utensils, house tanks, rarely in tree-holes, usually in the latter only when denied its natural breeding places.

Contrary to the belief held by some people that *Aëdes* (*Stegomyia*) *ægypti* occurs in ground water, it may be definitely stated that this species never breeds there. It has been found in a puddle hole where it was known that a traveller's water-bag had been emptied. I know of no record where the larvæ of this species have been found in dirty, much less foul, water.

Prevalence.

It is well known that mosquitoes do not feed as often in the winter as in the summer. It is also established that *Aëdes* (*Stegomyia*) *ægypti* requires a blood-meal to ensure the fertility of the egg before each batch of eggs is laid. Therein lies an extremely important factor in determining the relative decrease in numbers of mosquitoes in winter.

There is not the great seasonal difference, commonly supposed, in the prevalence of mosquitoes in northern Australia, that is from Brisbane northwards. Of course there is definite decrease in numbers seen during the winter, but because of such factors as, in particular, a disinclination for active feeding, they become less obvious to the community, with the result that the absolute decrease noted assumes in popular conception much greater, but nevertheless unreal magnitude.

During the winter of 1942 domestic and sylvan species of mosquitoes in Cairns were just as abundant as in the middle of summer. There is a " slowing up " of mosquito breeding in southern Australia; nevertheless there is no hibernation except perhaps in the snow belt.

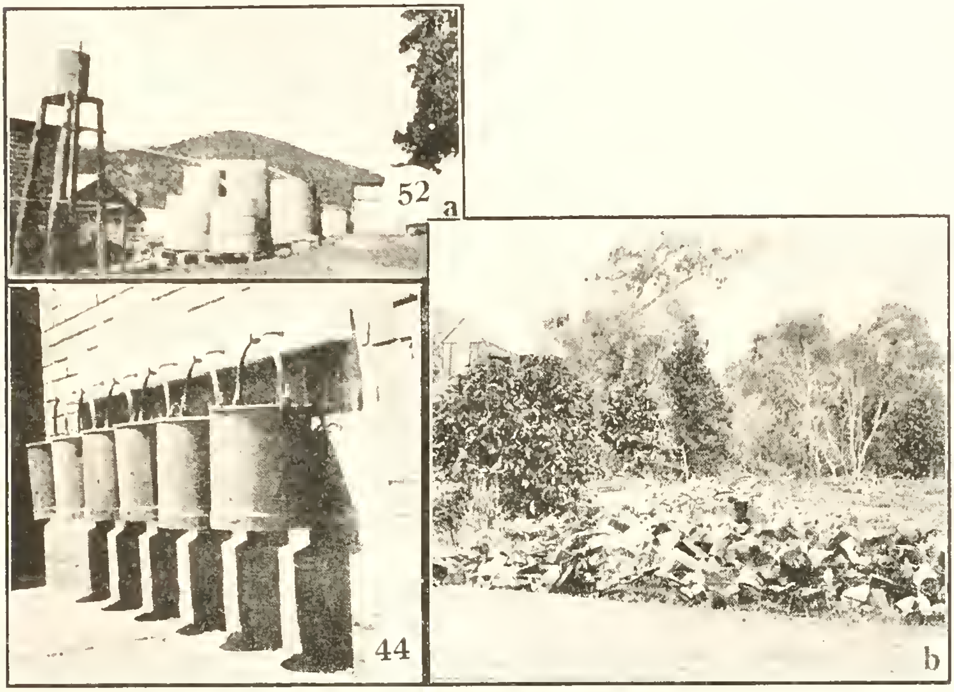
Larvæ of all ages and pupæ may be found throughout the year in southern New South Wales, thus conclusively proving that there is breeding throughout the winter; similarly, adults may be found amongst the grass growing near breeding grounds.

CONTROL.

It is a simple matter to control and eventually exterminate *Aëdes* (*Stegomyia*) *ægypti* provided that the assistance of the public is obtained and that the same directions are always given. The best means to adopt, in addition to the work done by a fully trained staff, is to give detailed instructions in simple language to school children.

The larvæ of this mosquito are found in all receptacles holding *clean* water in and around buildings, from the fire sprinkler tank on the top of city buildings to the paint-brush

tin and the sump-pit in mines. House tanks (Fig. 52*a*), sagging roof guttering, flower vases, water in the ant protectors of meat safes and the like, are all actual places where the larvæ of this species are to be found. Garbage depôts (Fig. 52*b*) when close to buildings are potential breeding places for this mosquito since such situations always contain disused tins and bottles capable of holding water.



Figs. 44, 52*a*, *b*.—Breeding places of *Aëdes* (*Stegomyia*) *ægypti*.

It naturally follows that all disused tins and bottles must be gathered up, completely destroyed, and buried in pits which when filled to within two feet of the top must be covered with soil to the level of the surrounding earth. The practice of local authorities of dumping such material without destroying it beforehand in swamps and suchlike situations is pernicious.

Therefore house-tanks must be made mosquito-proof, permanently for preference, but when this is impracticable, as at the present time, due to the lack of the correct type of gauze, then temporary measures must be instituted—oiling.

Wire Gauze.

The correct type of gauze (Fig. 65) to use is either that made from brass or from bronze. The mesh to use is 18, and it must be made of 33 gauge wire. The size of the hole in this gauge is such that a mosquito cannot escape from a house-tank or get into one. The gauge of the wire is important since the size of opening depends on the two factors of mesh and diameter of wire, i.e. a finer gauge wire results in a larger opening for the same mesh. The strainer of the manhole and the overflow pipe must be securely gauzed. In addition the manhole must be carefully made so that the strainer will fit exactly, leaving no spaces between its edge and the strainer.

Oiling.

In the absence of wire gauze the use of 150° test kerosene oil is used with entirely satisfactory results—one eggcupful *once* per week to each house-tank. It matters not whether the mosquito larvæ die in two hours or four days when using this quantity of kerosene. The fact remains *that they do die and that that amount of kerosene does not taint* the water, whereas larger quantities of kerosene do taint the water. It has been recommended that fly-spray should be used instead of kerosene. The use of fly-spray in place of kerosene cannot be too strongly deprecated, for we know nothing of the effect upon the person of increasing doses of pyrethrin (the soluble active principle of pyrethrum). There may be no harm in its use but for aught we know to the contrary there may be.

All household water containers must be completely emptied *at least* once per week. This prevents larvæ contained in such utensils from reaching maturity, pupating, and giving rise to adults.

Control of Adult Mosquitoes by Spraying.

All adult mosquitoes must be attacked with a good quality fly-spray in their hiding places—behind doors, on and under window blinds and curtains, under beds, tables and suchlike situations where the direct rays of the sun do not penetrate. This is necessary because, as has been found in the case of Anopheles and its larvæ, it is useless to attempt to control a disease unless both the larval and adult stages of the intermediary host are attacked.

Unusual Breeding Places.

When all domestic water containers have been dealt with and the adults have been, at least, controlled by the use of fly-spray, those female specimens which have escaped will lay their eggs in rot-holes (Fig. 53) and depressions in *trees and stumps provided these situations are close to habitations.* The complete eradication of the breeding of this mosquito in such situations is brought about by the use of sawdust thoroughly impregnated with coal tar. This preparation requires renewal about every four weeks, or following a period of heavy rainfall. Cement or earth filling is useless, as in the case of living trees and stumps the bark shrinks away from the filling, thus permitting water to collect in the cracks.

Genus *Culex* Linnæus.

Culex Linnæus, *Syst. Nat. Ed.*, X, 1758, 602.

" *Characters.*—Adult : Eyes usually touching for a considerable space above antennæ, usually also on under surface below mouth-parts. A continuous row of orbital bristles bordering eyes. Proboscis of more or less uniform thickness throughout (very slightly swollen at tip in subgenus *Melanoconion* and in a few other cases), curved forwards in repose and rarely much longer than front femur. Palpi of ♂ long or short ; when longer than proboscis the last two segments are slender, upturned, usually subequal in length and hairy. Palpi of ♀ rarely

Fig. 53.—An unusual breeding place of *Aëdes* (*Stegomyia*) *ægypti.*

more than one-fifth as long as proboscis, and usually without the small terminal segments which are often found in other genera. Antennæ of ♂ usually distinctly plumose, the last two segments elongate, hairs of verticils evenly spread round the segments. Antennæ of ♀ with all the flagellar segments (including the first and last) subequal in length. Vertex always with very numerous upright forked scales; decumbent scales usually narrow, but sometimes broad and flat, especially around eyes. Thorax rarely with conspicuous ornamentation. Mesonotal bristles well developed; scales usually all narrow. Pronotal lobes widely separated. Posterior pronotal lobes ('pro-epimera') with 4–6 or more bristles in a posterior row. Spiracular bristles absent, as are the post-spiracular. Pre-alar, sternopleural and upper mesepimeral bristles well developed; lower mesepimeral usually reduced to one, sometimes absent (more numerous in subgenus *Lutzia*). Postnotum without setæ. Pleuræ usually with small patches of scales, sometimes bare, but never very densely scaly. Upper margin of meron above level of base of hind coxa. Abdomen: Hypopygium of ♂ with the coxites somewhat conical, without basal lobes or claspettes, but with a subapical lobe bearing a number of more or less modified bristles: style usually sickle-shaped, working in a vertical plane; anal segment better preserved than in the other genera, the paraprocts with a tuft of hairs or spines or a transverse comb of teeth at the tip; phallosome divided into a pair of plates with variously developed teeth and processes. Eighth segment of ♀ abdomen short and broad, though never completely retracted; cerci always short. Legs slender; femoral and tibial bristles usually inconspicuous. Hind tibia without close-set row of hairs on inner side at tip (except some-

times in subgenus *Neoculex*). First segment of hind tarsus as long as or somewhat longer than tibiæ, rarely slightly shorter. Claws of front and middle legs of ♂ unequal, the larger and usually also the smaller with one tooth; hind claws of ♂ and all claws of ♀ always simple. Pulvilli (Fig. 54) always present (well-developed except in subgenus *Lasiosiphon*, where they are quite small and only detected with difficulty). Wings with cell R_2 usually longer, often much longer than its stem. *Sc* usually extending well beyond end of *Rs*. Vein *An* ending well beyond level of base of cubital fork. Cross-vein *m-cu* well before *r-m*. Membrane with distinct microtrichia. No hairs present at base of radius, either above or below. Alar squama usually with a complete fringe of hairs; rarely (in a few of the smallest species) the fringe is incomplete, but never absent.

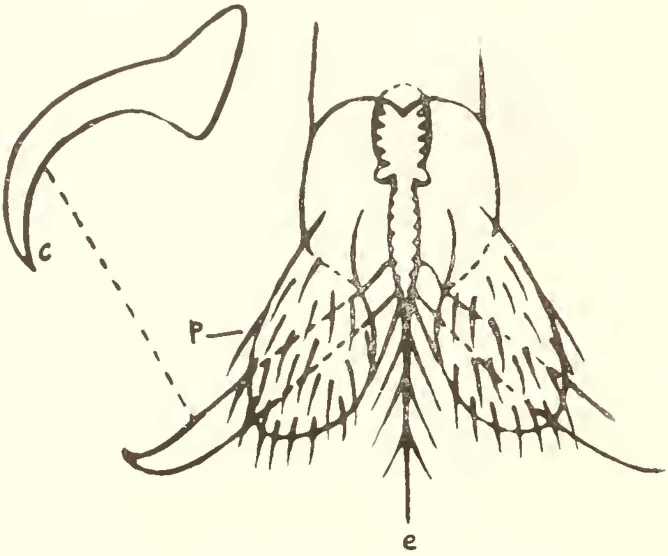


Fig. 54.—Apex of tarsus of ♀ *Culex*, showing simple claws and pad-like pulvilli. *c*, claw; *e*, empodium; *p*, pulvillus.

"*Pupa.*—Without special modifications. Respiratory trumpet usually of moderate length and with small opening. Dendritic tufts on first abdominal segment well developed. Paddles normal in shape, usually with two very short apical hairs placed side by side, or a subapical hair in addition to the apical; margin always smooth, without fringe.

"*Larva.*—Mouth-parts not specially modified, except in the predaceous subgenus *Lutzia*. Mouth-brushes usually very dense, composed of simple hairs. Antennal tuft usually beyond middle. When (as is usually the case) the antennæ are long, the subapical bristles are often well removed from the tip. Thoracic hairs usually long and branched; inner shoulder-hairs well developed and usually set in distinct chitinized plates. Usually one long simple hair in the propleural group, the other three shorter; plates of the large meso- and metapleural groups moderately large. No air-sacs in thorax. Abdomen without dorsal chitinous plates except on the anal segment, which is usually ringed by the plate in the fourth stage. Sub-siphonal tuft of eighth segment nearly always large, better developed than the dorso-lateral tuft. Siphon usually long or very long

(though occasionally very short), almost always with well developed pecten and several pairs, or a median row, of ventral tufts, often also with scattered lateral and dorsal tufts. Outer pair of hairs at tip of anal segment long and usually simple, inner shorter and branched. Comb usually forming a triangular patch, but teeth sometimes forming a single row. Ventral brush of anal segment (except in *C. moucheti*) well developed, with conspicuous barred area at base.

"*Eggs.*—Usually long, narrowed at one end, without conspicuous markings on integument or other modifications.

"*Habits.*—So far as known the eggs are almost always fixed together into raft-like masses, and deposited on the surface of water, the young larvæ emerging by bursting off a cap at the lower (larger) end; the only known exceptions are found in the subgenus *Microculex*, in which the eggs are each enveloped separately in a gelatinous covering. The larvæ are found chiefly in ground-pools of a more or less permanent nature, well provided with vegetation, but also in almost all other types of water, including that which collects in tree-holes, bamboos and Bromeliaceæ. The females feed chiefly at dusk or during the night; many species suck mammalian blood, others (or sometimes the same species) have been reported to attack birds, lizards and frogs.

"*Classification.*—The genus *Culex* was formerly understood, in a very wide sense, to include all Culicidæ with long palpi in the male and short in the female. Theobald restricted the extent of the genus, but it was defined in a different way by Dyar and Knab, whose interpretation is now followed in the main, although the genus has again been enlarged somewhat to include *Lutzia*, *Carrollia* and *Melanoconion*.

"As in the case of *Aëdes*, forms with either long or short palpi in the male are now included in *Culex*, this feature having been shown to be of small importance. The species with short male palpi are not all closely related, and therefore cannot be segregated into a single genus or even subgenus. A study of the hypopygium and other characters shows not only that the Oriental and Neotropical forms belong to different sections of the genus, but even that among the Neotropical forms with short palpi there are several groups distinct in origin. It may be convenient to separate the species with palpi alike in the two sexes, but in order to maintain a natural system it will be necessary (as in the case of *Aëdes*) to recognize several subgenera showing this feature.

"The characters on which the subgenera of *Culex* are defined are chiefly found in the hypopygium; in some cases the male palpi or antennæ have been used. No satisfactory distinctions between the subgenera have yet been found in the females, still less in the larvæ."

Culex annulirostris Skuse.

Proc. Linn. Soc. N. S. Wales, XIII, 1889, 1737; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 23.

♀.—Head dark brown, with pale brown narrow-curved and dark and pale upright forked scales and white lateral ones; antennæ dark brown, tori blackish, base of third segment pale;

palpi black apex with a few white scales; proboscis blackish-brown with a broad median white band as in figure.

Thorax dark brown, clothed with brownish narrow-curved scales, scutellum dark brown with pale narrow-curved scales, border bristles dark brown; pleuræ brown with patches of white flat scales.

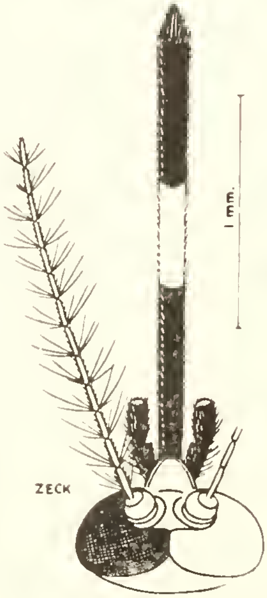


Fig. 55.—*Culex annulirostris* Skuse. ♀ head.

Wings: Veins clothed with dark brown scales; first fork-cell longer and narrower than the second, base of latter nearer base of wing; stem of first fork-cell slightly more than half the length of the cell, that of second fork-cell as long as its cell; cross-vein 4–5 about two and a half times its own length from cross-vein 3–4.

Legs: Brown, basal half of femora mottled with white scales beneath, hind femora with a pale knee spot, hind tibiæ pale at apex; tarsals I–III with creamy-white basal banding.

Abdomen: With blackish-brown scales with narrow white basal banding and white lateral spots; first segment with numerous pale bristles, venter white scaled.

Larva: Head with "preclypeal seta simple, peg-like. Preantennal situated slightly behind and internal to base of antenna, 8–10 branches, large and plumose. Postantennal setæ represented by a group of three close together; the most anterior and internal of these (presumably the inner post-antennal seta) simple, fine and long; the other two (presumably middle and outer postantennal) with 3–5 conspicuous long plumose branches. Mental plate with one large median tooth and six or seven subequal teeth on each side. Basal part of antenna pale, beset dorsally with small spines, a large tuft of about forty plumose branches at three-fourths. The shaft beyond this point brown. Two long, stout setæ at eleven-twelfths. Terminally a long spine, a short spine, and a short, blunt process. *Thorax.*—There are no features which call for remark. *Abdomen.*—The first seven segments are not in any way remarkable. Eighth segment with a comb of about 50 scales arranged in a semi-circular area. Fringe of comb scales

long. Siphon pale brown, widest at base, with straight sides, ratio of length to breadth about 5 : 1. Acus conspicuous. Eleven or twelve subventral hair tufts irregularly arranged so as not to form definite pairs. First hair-tuft at three-eighths, last at three-fourths. Each tuft consists of 6–10 simple branches, longer in the basal than in the distal tufts. Pecten teeth 12–15 similar to one another, extending from base of siphon to just beyond one-fourth, that is to say, not overlapping with the ventral hair-tufts. Each tooth with about six denticles, which are distributed along its entire length. Ninth apparent segment well chitinized, the dorsal plate extending right down to the ventral surface of the segment. Dorsal terminal setæ few (about four on each side) stiff and simple. Ventral fin well developed, consisting of about twelve primary members, each dividing close to the base into a large number of branches which are not plumose. Anal gills equal in size, lanceolate " (Buxton and Hopkins, 1925).

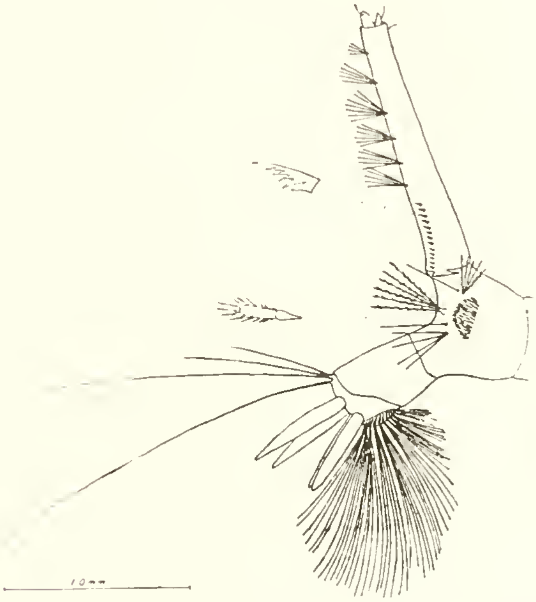


Fig. 56.—Apical segments of fourth stage larva.

Distribution.—Australia ; apparently throughout the Pacific Islands, including New Guinea.

Bionomics.—The larvæ of this mosquito are to be found for the most part in fresh water swamps and occasionally in brackish water.

The adult comes into houses at night time to feed. I have not found this mosquito biting during the day time.

Relation to Disease.—An intermediary host of *Wuchereria bancrofti*.

Culex sitiens Wiedemann.

Aussereur. Zweifl. Insec., I, 1828, 542 ; Taylor, Check List Culicidæ Australian Region, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 24.

♂ and ♀.—General colouration brownish-black.

Head: With narrow brown and upright black scales on vertex and nape, and broad pale scales low down at each side. Proboscis black, with a creamy band in middle, of about same width in the two sexes. Palpi of ♀ black, with white scales apically: in ♂ with two pale rings on long segment, narrow basal pale rings to last two segments, tips rather broadly pale, otherwise outstanding hairs on last two segments are dark; a row of stiff translucent hairs projecting downwards from underside of long segment . . .

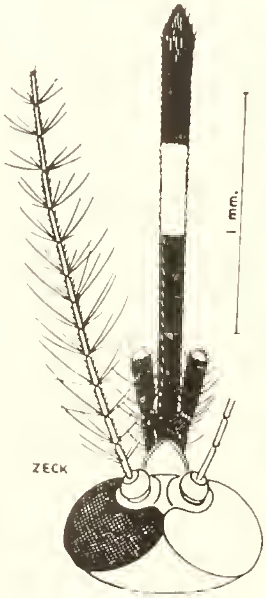


Fig. 57.—*Culex sitiens* Wiedemann. ♀ head.

Thorax: Mesonotum covered with dark brown narrow scales, usually some paler scales towards lateral margins. Scutellar scales narrow and pale brown.

Wings: Scales dark and moderately broad: fork cells rather short, base of anterior slightly nearer wing-tip than that of posterior.

Legs: Brownish-black; anterior surface of femora speckled with pale scales, most marked on mid-legs; mid- and hind tibiæ with a pale line on the outside, not always very pronounced. Tarsi with distinct, but rather narrow, basal and apical pale rings.

Abdomen: Tergites brownish-black, with rather narrow basal white bands.

♂.—Terminalia: Lateral plate of phallosome comparatively large; median process with several teeth, one larger and longer than others.

Larva.—Head pale, with faintly darker patches in some specimens; antenna (Fig. 58*a*) very similar to that of allied species, the larger part of the shaft pale, darker at the extreme base and along the apical part between the tuft and the tip, the tuft arises at a point nine-sixteenths to five-eighths of the length from the base; mentum (Fig. 58*b*): eight moderately large teeth on either side of the central one. *Comb of the eighth abdominal segment* formed of about thirty small teeth in a triangular patch . . . the teeth are of the form common to many

species of *Culex*, with lateral fringes of minute spines or hairs (Fig. 58*c*).

Siphon (Fig. 58*d*): Short, widest at base, pale brown, darker along the basal edge and at the apex; index 2 to 2·5; five pairs of tufted hairs along the posterior border and one pair of lateral tufts: pecten normally of nine to eleven moderately large teeth (one specimen has extra teeth alongside the main rank, the total number being fourteen), each tooth has a number of small lateral denticles from the base to the apex (Fig. 58*e*); aens moderately developed. *Anal segment* (Fig. 58*f*): Chitinous ring thin and rather narrow especially ventrally, some minute spines along the posterior margin towards the dorsum; outer subdorsal hairs each divided into two or three branches, inner pair single and long as usual; lateral hair single, occasionally double, and as long as the segment; anal papillæ small; anal fan formed of about twelve hairs each split into ten or twelve branches (Barraud, 1924).

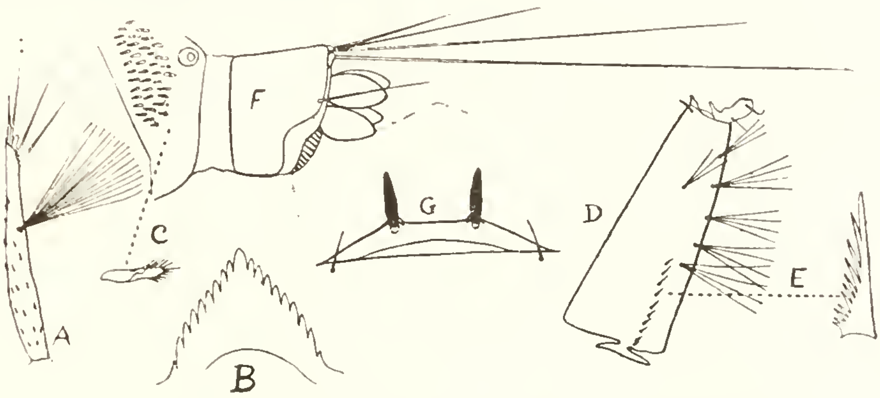


Fig. 58.—*Culex sitiens* Wiedemann. Larva. *A*, antenna; *B*, mentum; *C*, comb scales; *D*, siphon; *E*, pecten teeth; *F*, terminal segment; *G*, clypeus. *After* Barraud.

Pupa.—*O* a strong tuft of about six branches; *P* as long as *O*, two to three branched; *R* only half as long, weak, with two to four branches. *K* double as usual; *S* single, but not much longer than *K*; float-hair large, more highly branched than *C. bitæniorhynchus* and with large palm. *C*–II a short, many branched dendritic tuft. *C*–III–IV with about six branches, *C*–V–VI with three, all a little over half as long as segments. *B*–III–IV double or triple, rather shorter than segments, *B*–V–VI double, about equal to segments. I–II not very long, equal to *S* as usual; I–III–VI double. *A*–VII with four to five, *A*–VIII with ten to twelve branches of normal length (Edwards, 1941).

Distribution.—Common in northern Australia and New Guinea, extending to Fiji and Africa.

Bionomics.—Larvæ are found in fresh and brackish water in swamps and casual pools.

Relation to Disease.—A relatively poor intermediary host of *Wuchereria*.

Culex fatigans Wiedemann.

Aussereurop. Zweifl. Ins., I, 1828, 10; Taylor, Service Publication (School of Public Health and Tropical Medicine), No. 1, 1934, 24.

Fig. 59.—*Culex fatigans* Wiedemann. Life history showing egg raft, larva, larval skin, pupa, pupal skin and ♂ adult.
[Photo.—G. Burns.

♀.—Head : Vertex and nape covered with narrow golden-brown scales and scattered upright scales, latter more numerous on nape, a patch of broad pale scales low down at each side. Palpi brown, about one-sixth length of proboscis ; latter dark brown, usually with an indistinct paler area about the middle, especially on underside and sides ; labella pale brown.

Thorax : Mesonotum, scutellum, *apn* and *ppn* covered with narrow golden-brown scales. From front of mesonotum two submedian dark bare lines run back a short distance, narrowing posteriorly. Pleuræ brown, with two patches of broad pale scales on mesepimeron and two on sternopleura (none on post-spiracular area). No definite dark areas.

Wings : Dark scaled, outstanding scales narrow.

Legs : Brown, dark brown, or nearly black when viewed from front or from above ; paler, especially femora, when seen from behind or from beneath ; hind femur dark brown on dorsal border on outer side, otherwise pale ; femora with very small knee-spots, hardly visible, except on hind pair. Mid- and hind tibiæ usually marked with a narrow yellowish ring at apex. Tarsi entirely dark.

Abdomen : Tergite I almost entirely covered with long yellow hairs, a patch of dark scales on apical border in middle ; II–VII dark brown or black, with transverse ochreous (not white) basal bands, a little wider in middle than laterally, lateral borders of VI and VII, and usually whole of VIII, pale scaled. Sternites entirely covered with pale scaling.

♂.—Palpi longer than proboscis by rather less than length of terminal segment ; long segment with narrow pale ring on basal half, and usually with a rather wide indefinite pale area near apex ; apical one-third of long segment and last two segments with outstanding dark hairs ; a line of white scales on under surface of penultimate segment ; a spot of white scales at base of terminal segment on underside. Pale abdominal bands usually wider than in ♀.

Fig. 60.—Male terminalia.

Terminalia with the lateral plate of phallosome very characteristic; paraproct usually with a small lateral arm.

Larva.—Head, antenna, mentum, siphon and anal segment as shown in Fig. 61. (Thoracic chætotaxy as shown in Fig. 62.) Comb of 35–40 small fringed teeth in a triangular patch. Siphon usually about four times length of diameter at base.

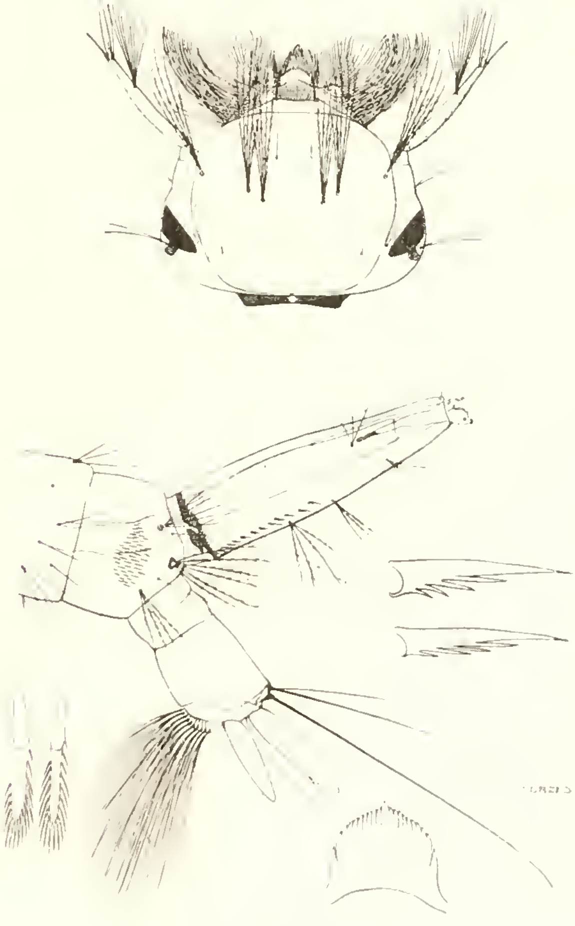
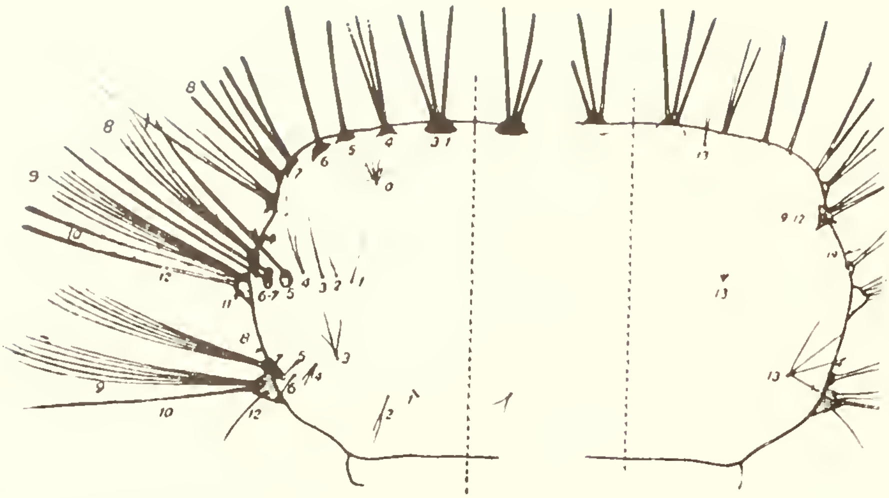


Fig. 61.



Chætotaxy of larval thorax of *Culex fatigans* : left, dorsal right, ventral.

Fig. 62.

Pupa.—Paddles large and slightly pear-shaped, with a well developed midrib, external border slightly thickened, no fringe. Two closely placed setæ at the distal end of midrib. There is a tuft of six to eight branched hairs at the posterior angle of the eighth segment. There is a group of three setæ at the posterior angle of the seventh segment ; the one near the angle is a small tuft of four to five hairs, immediately above it is a larger tuft of three to five stout hairs, usually subplumose, but may be branched, internal to this seta and above it is a small double or triple hair. The sixth segment has, just above its posterior angle, a long triple hair ; somewhat internal to the angle on the posterior margin a long delicate triple hair is situated and just internal to it is a tuft of four hairs. Fifth segment similar to sixth but the tuft internal to the posterior angle is usually composed of five hairs. The long lateral hair on the fourth segment is sometimes double, or quadruple, tuft internal to it with five to seven hairs. The tuft on the third segment, situated on the posterior angle, is composed of seven or more hairs. The dendritic hairs on the first segment are well developed. The pupal trumpets are comparatively short.

Distribution.—It occurs throughout Australia and is widely distributed in New Guinea. Widely distributed in the sub- and tropical world.

Bionomics.—Found throughout the tropics and subtropics it is one of the most troublesome domestic mosquitoes. It is almost exclusively a night feeding species. The first egg-raft is usually laid about two to three days after the first blood meal.

This mosquito lives for a considerable time, up to three months, in captivity and confined in a breeding cage eight by eight by sixteen inches lays regular batches of eggs after each blood meal. It breeds, for preference, in dirty water, e.g. liquid manure tins, septic tanks and their effluent, street gutters and suchlike situations. It will breed in clean water, e.g. house tanks. It is essentially a domestic mosquito. This species has been known to fly a distance of three miles.

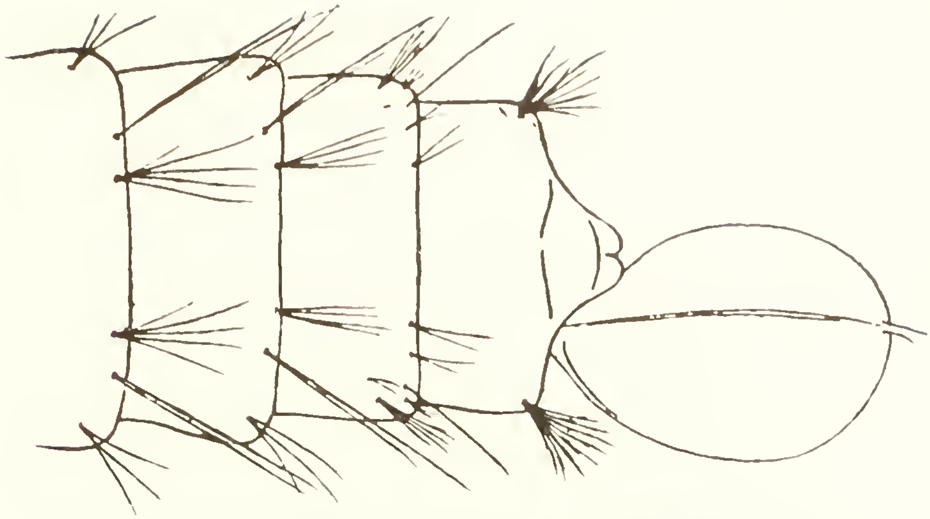


Fig. 63.—*Culex fatigans* Wiedemann. Apical segments of pupa.

Relation to Disease.—A most efficient intermediary host of *Wuchereria bancrofti.*

The control of *Culex fatigans* is in many cases the same as that of *Aëdes* (*Stegomyia*) *ægypti* since both of these mosquitoes are purely domestic, with the difference that *Culex fatigans* also breeds in polluted water. In cases where it breeds in the intake of septic tanks it is impossible to use oil of any kind, since the oil would interfere with the action of the chambers. However, by using petrol one obtains quick action and excellent results. Since petrol is explosive in air, no smoking is permissible in the neighbourhood of spraying operations. Street gutters carrying pot-holes of water, dirty or otherwise, should be sprayed once per week until such time as the gutters are repaired.

For further details of control, see under control of *Aëdes* (*Stegomyia*) *ægypti*, page 92.

Woodhill and Pasfield's (1941) illustrations do not correspond with those of the same species in other works, such as the drawings by Terzi, of *Culex fatigans.*

COLLECTING LARVÆ IN THE FIELD.

For the purpose of collecting mosquito larvæ I have always used a white enamel ladle, about six inches in diameter, using a pipette for transferring the specimens to a bottle. After years of experience I have found that a bottle with a gradually sloping neck is the safest type to use for the transportation of larvæ. By using this type of bottle, finally two-thirds filled with water before making the journey home, the larvæ never get knocked about by the movement of the water even when riding a push bicycle on a bad road.

Larvæ found in similar situations may be put into one container. Those found in shaded situations should not be put in the same bottle as those from water exposed to the sun.

It is important to bring back sufficient water from the swamps for use in the breeding dishes. For the latter I have found white enamel basins about five inches in diameter quite serviceable, the depth of water being about two and a half

inches. Another good method entails the use of enamel dishes about two inches deep and about a foot square. Larvæ as they mature may be picked up with the pipette and placed in 6×1 test tubes, the latter being placed in wooden racks. By this means the fourth stage larval and pupal skins are saved, placed in a small vial; half drachm vials are suitable and given the same number as the adult. It is necessary after the larva pupates to use a cotton wool plug in the test tubes. If the individual skins are not required the pupæ may be picked up and placed in an enamel basin of clean tap water and put in a breeding cage.

The most serviceable type of breeding cage that I know is one designed by Dr. (now Wing-Commander) A. H. Baldwin and the late L. E. Cooling, which has never been described. It consists of a wooden floor, thoroughly seasoned, sixteen by eight by one inch; in the four corners one and one-quarter inch in from the edge a three-eighths hole is bored. A frame is made of three-eighths steel rod eight inches high and eight inches wide, the two ends each being bent at a double right angle to form a foot and toe, the latter to fit into the holes. A mosquito net is fashioned, with a sleeve, to fit over this frame. This cage has very distinct advantages since it can be easily dismantled and packed away for travelling.

When doing an *Anopheles* survey it is essential to have at least two maps—on a sufficiently large scale. One should be used for tabulating the breeding places not only of the Anophelini but also of the Culicini. This can be done without clogging the map by the use of coloured inks. The second map should be used for indicating the breeding places of mosquitoes which are known to be intermediary hosts of disease. The presence of algæ, especially *Spirogyra* sp., should be noted, for their presence usually denotes the presence of *Anopheles* larvæ.

It is necessary to note the presence of every pool of water no matter how small it may be, and to note whether it is exposed to the sun or only partly so.

It is very important to collect all the adult *Anopheles* possible, some of which must be brought back alive for dissection for age determination.

If malaria is present all the adult *Anopheles* seen must be captured alive and dissected to determine which of the species is the intermediary host and the ratio of mosquito infection per species.

I have always used a cyanide killing bottle in preference to a chloroform one, for I found that the latter always "sweated", thus spoiling the specimens, and should the stock chloroform bottle be broken when on an expedition one was without a killing agent.

The bottle I use has a two-inch base, neck opening one inch, length of neck one inch, overall length four inches. The cork is of first quality bark, not rubber. The cyanide, broken into a fine powder, is one inch in depth, firmly tamped down with a glass rod; next a quarter-inch layer of plaster of paris is added, then I mix *dental* plaster of paris with water into a cream that will just run and pour that on top of the layer of dry plaster. The bottle requires to be tapped on a wooden bench if and when

bubbles appear so as to shake them out. When this has been done I wipe off any plaster from round the inside of the neck, fill the bottle with torn up pieces of blotting paper to take up the excess moisture, cork and leave stand for a few hours. Finally the pieces of blotting paper are removed, the bottle cleaned up, a few more pieces of blotting paper added to make sure that all the moisture has been taken up; after a couple of hours the blotting paper is removed and the bottle is ready for use. It must always be kept tightly corked.

I understand that a serviceable chloroform killing bottle is made by placing some old rubber pieces in a bottle, pouring on the chloroform and corking it until the rubber has absorbed the chloroform. If there be a surplus of chloroform, it is poured off, the bottle wiped out, a piece of white blotting paper pushed down on to the rubber and corked. This type of killing bottle is said to last for some weeks.

There are in Australia and New Guinea, as elsewhere, two main groups of *Anopheles*, the larvae of which require the maximum amount of sunlight (*amictus-punctulatus* group) and those which require the minimum amount of sunlight (*bancrofti*). Before what we now know of the ecology of the various species of *Anopheles* was understood, it was thought that all that was necessary was to change one character of the breeding place, i.e. the amount of sunlight. So if a dangerous species was breeding in the shade the trees were cut down or if breeding in sunlight, trees and shrubs were planted without regard to the fact that by doing so we were letting it an equally dangerous species with in some cases almost disastrous results. One Australian example may be instanced: the swamps in and around Cairns are for the most part heavily overgrown with vegetation. There are two that have scarcely any vegetation growth and are open to sunlight. *Anopheles amictus*, *A. annulipes* and *A. punctulatus* var. *moluccensis* are breeding in these two swamps while *A. bancrofti* is the main species in all the others. *A. annulipes*, *A. punctulatus* var. *moluccensis* and *A. bancrofti* all transmit malaria, so that if we destroy vegetation in the overgrown swamps to get rid of *A. bancrofti* we will let in *A. annulipes* and *A. punctulatus* var. *moluccensis* or the converse if we plant trees and shrubs in and around the swamps where *A. annulipes* and *A. punctulatus* var. *moluccensis*, are breeding then we will let in *A. bancrofti* and drive out the others. Naturally the only method to adopt in regard to the swamps at Cairns is to fill them in.

The breeding places of Anophelini in particular and Culicini in general may be stated as follows:

All ground water, whether in the sunlight or not, and no matter how small the quantity may be—hoof prints of cattle and horses, shallow depressions on the ground, ruts in bush tracks, permanent swamps, overgrown or otherwise, along the grass-grown banks of rivers and creeks, borrow-pits alongside railway lines, pot-holes in dried-up rivers and creeks. Some specialized Culicini breed in rot-holes and hollows of trees, at the base of the leaves of taro (*Colocasia* sp.) and other similar plants, pitcher plants and the leaf axils of such trees as *Pandanus* sp.

We have in Australia one species which breeds in salt water—*Aëdes* (*Pseudoskusea*) *concolor*—which is only found in rock pools on the sea shore, usually just above tide level, but well within reach of king or spring tides. It does not breed in fresh water. Species such as *Aëdes* (*Ochlerotatus*) *vigilax* are not salt water breeders, since it is exceptional for them to be found there. This mosquito breeds freely in fresh water.

It is commonly stated that mangrove "swamps" are prolific breeding places of mosquitoes, but I have failed to find them breeding in these places in Australia, Papua, or New Guinea. I have not seen any such place that is not fully subject to tidal influence in Australia or New Guinea.

Anthropophilous and Zoophilous Habits.

We know nothing in Australia on the predilection of our various species of *Anopheles* for human or other blood. I have but one note which relates to *A. annulipes* in Victoria, where at the time (December, 1916) they were abundant. I found that *Anopheles annulipes* would attack man or cattle and horses with equal avidity when one stood close to either a horse or cow.

P. H. van Thiel (1939) has published a paper upon work carried out in the Netherlands Indies. The review published in the *Review of Applied Entomology*, B, XXVIII, 1940, 10 is extracted here in so far as it relates to Australian species.

"The investigations described in this paper were carried out to determine the factors responsible for the feeding preferences of Anophelines. In this connection, three hypotheses have been advanced. Roubaud considered that the choice of food was determined by the maxillary index of the Anopheline (*R.A.E.*, B, 10, 53 ; 16, 210 ; 21, 140) ; Hackett and Missiroli attributed it to the odour of the host animal (19, 107) ; while Martini and Teubner held that feeding was induced by favourable microclimatic conditions (21, 137)

"The results are given of investigations on the maxillary indices of Anophelines in the Netherlands Indies. Owing to the method adopted, they have to be reduced by 1·6 to render them comparable with those obtained by the French method. Additions to the author's list (24, 90) are *Anopheles hyrcanus* var. *sinensis* Wied., *A. bancrofti* Giles, *A. punctulatus* Don., and *A. punctulatus moluccensis* Sw. and Sw., of which the indices were 14·6, 14·5, 14·5 and 14·7 respectively. The last three species are highly anthropophilous and dangerous in the eastern part of the archipelago, but their maxillary indices were higher than those of the other species, the number of teeth being sometimes 19–20. Roubaud's hypothesis seems in general to hold true for the Anophelines of the Netherlands Indies when formulated as follows : When the 'reduced index' is less than 12, there is a great risk that the species may be sufficiently zoophilous and therefore liable to transmit malaria ; when the index is 13–14 the species may be presumed to be zoophilous ; and when the index exceeds 14, the species may be again dangerous."

The Determination of the Intermediary Hosts of Malaria.

The determination of the local intermediary hosts of malaria plays an important part in any malaria or anopheline survey.

Two methods have been used in the past, the results of which are stated as the *index of experimental infection* and the *index of natural infection* respectively. Two schools of thought prevail as to the relative value of the results obtained.

Walker and Barber "believe that the experimental infections, if properly conducted, supply the more reliable index of the relative susceptibility of the different species. In mosquitoes examined for natural infection with malaria parasites, it is impossible to determine whether or not the mosquito has had an opportunity to bite an infected person; whether or not, if the opportunity presented itself, it was taken advantage of; if the mosquito did suck blood, whether or not the blood contained gametes sufficiently numerous to infect the mosquito; and whether or not sufficient time had elapsed after the feeding for the parasites to attain development. In properly conducted experimental infections all of these essential factors are under complete control. We are also of the opinion that it is strong, if not wholly sufficient, proof of the capacity of a mosquito to transmit malaria if it can be infected with the malarial parasite, and if the parasites develop sporozoites and infect the salivary glands, without subjecting healthy persons to the bites of the experimentally infected mosquitoes. It is improbable, although possible, that sporozoites should be developed, migrate to and infect the salivary gland of the mosquito, and yet be incapable of being injected into or of infecting man. As it is known that different species vary greatly in their ability to transmit malaria, it is of the greatest practical importance to determine the relative susceptibility of the different Anophelines in any country. In most infection experiments hitherto performed, careful comparative tests have not been made to determine the relative susceptibility of the different species of anophelines. In some cases a rough estimation of the proportion of a given species that becomes infected has been obtained. However, to be of practical value, the test should be comparative of the different species of anophelines in a given region. This can be accurately determined only by a large series of experiments in which the different species are fed at the same time upon the same malaria patients and in which only those mosquitoes that sucked a full meal of the infected blood are selected for dissection. Under these conditions of experimentation the percentages of infected mosquitoes and the relative number of oocysts in the infected individuals of the several species will give reliable index of the relative susceptibility of these anophelines to infection with the malaria parasite."

Swellengrebel, Schuffner and Swellengrebel de Graaf give a different viewpoint. They believe that the following questions must be answered, so as to ascertain whether a certain Anopheline may be considered an efficient intermediary host of malaria:

(1) Is the species abundant or scarce?

(2) Is it capable of maturing the malaria parasites?

(3) Has the species a predilection for human blood at all times—in the cage and in the "wild" state?

(4) Does it feed in the wild places far from human habitations, or does it regularly visit man in or near his dwellings, gardens, or plantations?

(5) What is the vegetable food of the females, and does it interfere with the development of the malaria parasite?

(6) Do these factors in its biology favour or impede this development?

They state that the determination of the experimental index is insufficient to incriminate a species, for it might result in one being led to consider as pernicious a species which under natural conditions does not live near men, or which is compelled to feed on man only when no other food is available; while another species not so well able to follow the development of the parasites, yet being a more vicious biter of human beings, is actually more dangerous than the former. They also point out that questions three to five are difficult to answer, while to answer six is almost impossible, since we do not know if such factors really exist, or if they do, in what do they consist; however, they point out that these difficulties are avoided if nature performs the experiments, by determining for each species in a malarious region the percentage of species which are naturally infected (*natural index*).

The malariologist must have on hand at the *same time* a patient whose blood is rich in gametocytes and an abundance of *Anopheles* mosquitoes. He must also know the breeding and feeding habits of the various species of *Anopheles* he is using in his experiments. For example the various species of *Anopheles* in Australia, so far as I am aware, do not bite man for about two days after emergence, also they may be kept alive on dried fruits, e.g. dates, sultanas, etc., but they will not feed on man immediately after feeding on dried fruits—a break of a day or two appears necessary. If the malariologist be not an entomologist with this specialized knowledge, then he must rely implicitly on the entomologist to breed and keep the adult Anophelines until he is ready to feed them upon a patient.

There is an aspect of malaria transmission that must not be lost sight of, i.e. *Anopheles annulipes* appears to be a relatively poor intermediary host under normal circumstances. Does such a species become dangerous should there be a considerable concentration of gametocyte carriers and a normal supply of *Anopheles* or *vice versa*? The answer is probably "yes".

Dissection Technique.

The female Anophelines will be found resting indoors early in the morning. They are fairly easy to see in European constructed houses by bending over and looking up the wall, when, if present, they may be seen by their characteristic resting attitude. When searching for Anophelines in native houses it is essential to use a torch. When seen, the specimen is captured by very carefully placing the mouth of a 6×1 test tube over it and carefully inserting a cotton wool plug in the tube. It is bad practice to put more than one specimen in a tube, because if this is done they will damage each other and such damage may preclude determination of the species with certainty. When the morning's catch has been made and all details of localities of captures entered in the field book, it is necessary to sort out the catch—those with fresh blood or partly digested blood in their abdomen, and those showing no sign

of blood. The test tubes must be numbered and corresponding number entered in the field book.

The specimens which show no sign of blood in their abdomen may be dissected, but those with blood in the abdomen must be held until after they have digested their meal, if possible until after the tenth day of feeding, to give the cysts an opportunity to develop on the stomach wall. It is waste of time and the spoiling of possibly important material to dissect mosquitoes with blood in the abdomen as the blood flows over the dissection obscuring the presence of cysts should the mosquito have previously fed upon a gametocyte carrier and become infective.

It is necessary to have the following instruments for dissecting mosquitoes :

(1) A killing bottle.
(2) A pair of angle-bladed scissors.
(3) Dissecting needle handles and a supply of No. 12 or No. 16 needles. The ordinary dissecting needles, as purchased, are useless because they are far too thick.
(4) A sharp, fine pointed scalpel.
(5) A supply of normal saline and 3 × 1 glass slides.
(6) A dissecting binocular microscope with a good range of objectives and eye-pieces. The Greenough Leitz is excellent.
(7) A pair of forceps.

When the specimens are killed they must be identified *before* they are dissected.

One specimen, only, at a time should be killed. When dead the specimen is placed on its *back* on a slide. Then cut off with the scissors the legs and wings ; catch hold of the specimen with the forceps by the proboscis and place on its back in a drop of saline on a fresh slide. Care must be taken to see that the drop of saline will spread easily. If it does not spread, the slide is greasy, and a fresh one must be used. Now very carefully make a nick on each side of the seventh segment with the point of the scalpel. Next transfix the thorax with the needle held in the left hand and with the needle in the right hand place it on the partially separated segments and *very carefully* exert gentle traction. After nicking the abdomen, place the slide on a black background since it is easy to follow the dissection as the white viscera appear. It will be seen that the stomach is wrapped round with fine filaments—the Malpighian tubules. These must be separated out and cut off after the dissection has been completed. If the mid-gut threatens to break, stab the thorax several times with a needle to loosen the anterior attachments of the mid-gut, and again exert traction.

If the dissection has been carefully done all the viscera will be pulled out, œsophagus and diverticula, mid-gut, Malpighian tubules, hind-gut and ovaries. Place remainder of mosquito on another slide bearing the same number. Now cut away everything from the mid-gut and remove to another slide, taking care not to damage the ovaries. Add a drop of saline and clear off all remaining debris with small strips of white blotting or filter paper. So as to avoid squashing the mid-gut have pieces, about 15 mm. long, of horse-hair or hair from a shaving brush and place one nearby the mid-gut before gently

lowering a No. 1 cover glass on to it. Place on one side for examination until *after* the salivary glands have been dissected.

Now place the remainder of the mosquito on a slide with a drop of saline on a dark ground with the head toward you.

Place the needle held in the left hand across the thorax and exert pressure until the soft parts about the neck bulge. Place the right-hand needle just behind the head and exert *gentle traction* toward yourself. The glands are dragged out attached to the head, when successfully accomplished. They are white refractile bodies. If they are not seen, press with the needle lying on the thorax and with the other needle scoop out such tissues as present themselves at the opening from which the neck has been torn. When they have been found, remove all tissues except the glands from the slide, and apply a cover glass.

Examination of Preparations.

"Examine the preparation of mid-gut under a one-sixth inch lens. The level at which the oocysts are to be sought for (i.e., outer wall of gut) is the same as that of the tracheæ, which should, therefore, first be brought into focus. These are readily seen as well-defined tubes with a spiral lining ramifying upon the surface of the gut.

"(*a*) The younger forms of oocyst are clear, oval or round bodies, about the size of a red blood corpuscle, containing definitely distinct pigment granules. Oocysts of malignant tertian show a clump of pigment resembling pepper grains. Those of benign tertian show yellowish or golden pigment in wisps, whilst those of quartan show rather coarse pigment in a clump. Quartan pigment may be black, but is sometimes as light coloured as the benign tertian form, from which it may be difficult to differentiate it. Malignant tertian pigment is considerably coarser than that of benign tertian. The latter is very delicate and in large cysts is, often, only to be seen by using the one-twelfth lens.

"(*b*) The larger forms have a distinct cyst wall, and still retain unmistakable pigment.

"(*c*) The largest have lost their pigment, and are clearly defined cysts (40–60 microns), filled with hundreds of sickle-shaped bodies (sporozoites), which escape on rupture.

"(*d*) At a later stage, after the rupture of the cyst, only its shrunken wall remains visible.

"If oocysts are not detected, then by moving the cover-glass slightly the stomach can be rolled over, and the preparation re-examined from another point of view. The large cysts of trematode parasites (100–200 microns) must not be confused with oocysts. The 'black spores of Ross' must also be distinguished.

"The preparation of the glands should also be examined under a one-sixth inch lens, later under a one-twelfth. Sporozoites are in length about twice the diameter of a red blood corpuscle, and are difficult to see in the intact gland in the fresh state. If pressure is made on the cover glass with a needle, so as to rupture an infected gland, hundreds of these may be seen as thin, rather glistening, curved rods, both in the cells of the acini of the gland and free in the surrounding fluid. They have the characteristic

movement, which is important from the point of view of diagnosis. Three kinds of movement may be observed: (*a*) the formation of curves, (*b*) the formation of ring-form contractions, and (*c*) locomotion, or forward movement. The movements are slow and continuous, never jerky.

"To confirm the diagnosis, press firmly on the cover glass and draw it along the slide so that the film is made on both cover glass and slide. Both should be dried in the air, fixed in alcohol, and stained with Giemsa or Leishman stain. When examined under a one-twelfth inch oil-immersion lens, the sporozoites appear as fusiform, sickle-shaped bodies with a central red mass of chromatin. They are about 14 microns long, with one end often more pointed than the other.

"*Objects of Dissection.*

"The chief object of dissection is to determine what species of *Anopheles* are carrying malaria in nature under the particular local conditions. To get a rate a considerable number of dissections, at least 100, are desirable. The percentage in each species infected (*a*) with oocysts in the wall of the mid-gut and (*b*) sporozoites in the salivary glands should be determined. To make rates, comparable species caught together should be compared: it must never be assumed that because a species is very abundant it is the main cause of malaria in the area, for it frequently happens that the most important carrier in the district appears to be present in comparatively scanty numbers.

"Another point of importance is the seasonal incidence of infection of the *Anopheles* in the area. This should be determined, when possible, by determining the rate at different periods.

"For scientific purposes it is always of interest to incriminate a species not yet known to transmit malaria in nature. If a sufficient number of a species of this kind is available, it is always worth making a special effort to find it infected. In the case of oocyst infection always note the character of the pigment, to determine, if possible, the species of parasite with which it is infected.

"The infection rate in India may be extremely low, requiring the dissection of several thousand *Anopheles* to obtain results, but at times (probably when transmission is active) it may reach 10 per cent.

"*Dissection of Mosquitoes to Determine Age and Condition of Females.*

"(*a*) Inspection.

"By inspection it can be told whether a female *Anopheles*—

(*a*) Is probably one that has lived some time or the reverse.
(*b*) Contains blood, freshly imbibed or more or less digested.
(*c*) Has the ovaries more or less developed.
(*d*) Is ready for oviposition.

"Perry divided Anophelines into four grades, according to the condition of the wings. In grade 1 are placed specimens with the wing well marked and the wing fringe practically complete; in grade 2 those with the wing fairly well marked,

but the fringe somewhat worn ; in grade 3 those with the wing decidedly shabby, and the fringe very much worn ; in grade 4 those with the wing actually threadbare. In a series of 514 dissections in the Jeypore Agency, 466 were placed in grades 1 and 2, 45 in grade 3 and one in grade 4. Four specimens were found with sporozoites in the salivary glands, all of which were in grade 3. It, therefore, appears probable that the largest percentage of salivary gland infections is likely to be found in specimens with worn wings, i.e., the older mosquitoes.

" Examination of an *Anopheles* by the naked eye or lens will show whether the abdomen is (*a*) thin and undistended, or (*b*) more or less swollen. In the former case examination of the middle line ventrally will show whether it is completely free from blood or whether a thin dark line, indicating a trace of blood, is present or not.

" If the abdomen is swollen three distinct areas can usually be made out : (*a*) nearest the thorax is a transparent area due to the distended air of diverticulum ; (*b*) next to this and occupying often a large part of the abdomen is the dark area due to ingested blood ; (*c*) if the ovaries are at all developed, an opaque white area is seen at the hinder end of the abdomen lying more or less dorsally on either side. A rough idea of the condition of the particular female can be made by noting the extent of areas (*b*) and (*c*).

" When a female with undeveloped ovaries takes a meal of blood almost the whole abdomen is dark. As the ovaries develop the opaque white areas due to the ovaries creep further and further forwards. Eventually almost the whole abdomen appears opaque and while the dark area (*b*) is confined to a narrow streak ventrally in the middle line. When this streak has entirely disappeared the ovaries are usually mature and the female will normally lay its eggs that night.

" (*b*) Dissection to Determine Age, etc.

" Useful information may be obtained by the examination of the ovaries in connection with age relation to the presence of breeding places and other matters. The development of the egg-follicle has been divided into five stages. In the first stage the protoplasm of the ovum is still free from granules, and this condition is only present during the first day of the mosquito's life. The presence of a considerable number of mosquitoes with ovaries in this stage indicates that there are suitable breeding places in the vicinity, leading to a steady influx of newly hatched adults. If no mosquitoes are present with ovaries in the first stage, it indicates that any *Anopheles* found have hatched out from breeding places which are no longer in existence, or have been carried by the wind for a long distance.

" A full account of the appearance of the ovaries in the various stages of development of the egg-follicle was published by Christophers in the second number of ' Paludism ' (1911) (now out of print). The article was reprinted in the ' Report on Malaria at the Assam Sugar Estates and Factories Ltd., Nalbari, Assam, 1921 ', by Christophers and Khazan Chand (Calcutta, Government Press, 1922). But as neither of these publications is likely to be available, an account of the condition of the ovaries may be useful and is here given " (Christophers, 1928).

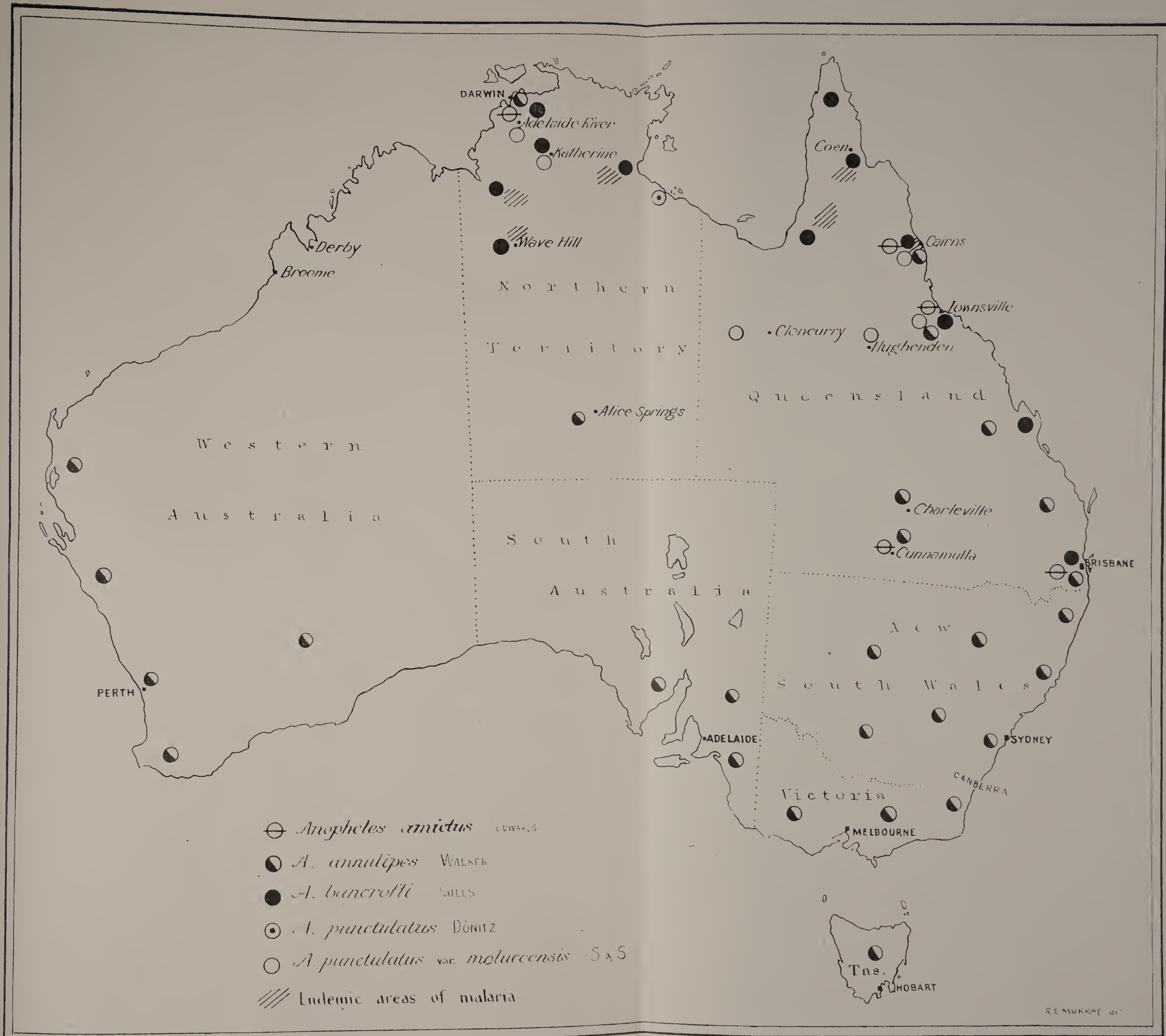

DARWIN
Adelaide River
Katherine
Coen
Derby
Broome
Wave Hill
Cairns
Townsville
Cloncurry
Hughenden
Northern Territory
Queensland
Alice Springs
Western Australia
Charleville
Cunnamulla
BRISBANE
South Australia
New South Wales
PERTH
ADELAIDE
SYDNEY
CANBERRA
Victoria
MELBOURNE
Tas.
HOBART
Anopheles amictus EDWARDS
A. annulipes WALKER
A. bancrofti GILES
A. punctulatus DÖNITZ
A. punctulatus var. moluccensis S & S
Endemic areas of malaria
R E MURRAY del

Fig. 64.

Endemic Areas of Malaria and Anopheles Distribution in Australia.

The endemic areas of malaria, as indicated on the accompanying map, Fig. 61, were marked for me on my atlas about ten years ago by Dr. C. E. Cook (now Major), sometime chief medical officer of the Northern Territory Medical Services, except the area near Coen, Cape York Peninsula, which was indicated by my colleague, Dr. A. H. Baldwin (now Wing-Commander).

Cairns used to be infected chiefly with benign tertian, sub-tertian, and to a less extent quartan malaria.* More recently the latter two forms of malaria appear to be absent. The area near Coen appears to furnish cases of sub-tertian malaria only.

The late Dr. Kortum informed me in 1912 that toward the close of the last century (1880–1895), when the Palmer goldfields of north Queensland were operating, there were many cases of malaria there, brought about by miners coming to the field from elsewhere in the tropics who were already infected with the malaria parasites.

The symbols designating the presence of the various species of *Anopheles* indicate their presence in the districts indicated and do not mean that the species in question is not found otherwise than marked.

We know too little, as yet, of the distribution of species to say that any given species does not occur in any particular area. We will probably find, for instance, that *Anopheles* (*Myzomyia*) *punctulatus* var. *moluccensis* has a more southerly distribution than at present known.

Anopheles amictus is a northern species, being apparently confined to Queensland, the Northern Territory and probably northern West Australia; there are no West Australian specimens in the School Collection. It extends into Netherlands New Guinea. *A. annulipes* was first made known in 1856 from specimens sent from Tasmania (probably from Hobart). It extends over the whole of the southern portion of Australia, where it is abundant and is found in the far north, but sparingly. I have taken it in Darwin. Belding (1942) states that this species is found in the New Hebrides. This is extremely doubtful and is probably based on an erroneous determination. *A. bancrofti* appears to be confined to Queensland and the Northern Territory but is probably present in northern West Australia and may possibly extend into northern New South Wales, as I have taken it in the suburbs of Brisbane. It is found on the mainland of New Guinea. *A. punctulatus* extends from the Molucca Islands to the 170° east longitude. There is one record for the Northern Territory; its variety *moluccensis* extends over the same west to east area and in addition is found throughout north Queensland and from Darwin to Katherine in the Northern Territory. It will probably be found further afield in the Northern Territory and probably throughout northern West Australia. *A. subpictus* extends from India, through Malaya, Netherlands Indies to Papua. Nothing is

* Breinl, A., and Taylor, F. H. (1918): *Med. Jnl. Aust.*, II, 109.

known concerning its Australian distribution. Whether it extends into the Territory of New Guinea and northern Australia has yet to be discovered. Svensson (1940) states that malaria does not occur east of meridian 160° or south of parallel 20°, also that malaria does not occur above 1,100 feet. These statements are unfornnately erroneous: 160° should read 170°, 20° should read probably 34°,* and 1,100 feet should read probably 4,000 feet.

Range of Flight.

We know practically nothing concerning the range of flight, in Australia, of mosquitoes, as no work has been done in this direction. I have but two records, firstly when travelling off the north coast of New South Wales on the northern lane, about ten miles off shore, a female specimen of *Anopheles annulipes* came on board and bit me. There was a very light offshore breeze at the time. Secondly, July, 1942, in Cairns, *A. bancrofti* came into my bedroom one night. The nearest breeding ground was half a mile away and it had to pass six streets of houses before entering my room.

With regard to our Culicine mosquitoes it would be pure conjecture to state anything about them.

That *Anopheles* mosquitoes are capable of travelling distances, it may be stated that Wallace (1939) liberated *A. maculatus* sprayed with painter's gold dust among mature rubber trees at various distances from the nearest coolie lines, where catches were subsequently made. The results proved that the adults can fly a distance of one and three-eighths of a mile, the greatest distance tested, and explain why seasonal waves and epidemics of malaria may occur in areas where oiling of breeding places is carried out up to a distance of half a mile from dwellings. de Burca (1939), working in India, records the fact that most of the mosquitoes found in the cantonment (at Quetta) breed outside its limits might explain the relative prevalence of *A. superpictus*, which is a large mosquito with a longer range of flight than *A. culicifacies* or *A. stephensi*; in one area rather large numbers were taken in July, and a search showed that the nearest breeding place was one and a half miles distant. The above findings dispose of the traditional half-mile safety line from the nearest breeding ground.

Fear has been expressed that *Anopheles* mosquitoes may be introduced into the Pacific Islands east of the 170° meridian. This seems somewhat doubtful because there has been ample opportunity for such introduction to have taken place in the past by means of inter-island lugger and small steamship travel. It may still be possible for it to take place today by means of the aeroplane, but if the fighting forces exercise the care they should, even for their own sakes, and spray out machines arriving back at their bases, then there should be but a very limited risk of the introduction of any insect pests into a new area.

But supposing some Anophelines did elude the vigilance of the Air Force hygiene staff in those ideas, I do not think that

* Since this went to press a case of benign tertian malaria has been reported from Bega, approximately 37° south, which had originated there (Tebbutt, A. H., *Med. Jnl. Aust.*, I, 1943, 476).

Anophelines or other mosquitoes would obtain a foothold in "American Polynesia", since the fish *Gambusia affinis* has long been established on many of the islands in the Central Pacific (Bryan, 1941). Therefore I do not think that any introduction of *Anopheles* could survive.

Mumford (1942) says: "The standard works of Edwards (1932) and of Taylor (1934), to which the medical entomologist would naturally refer, are also misleading in that they fail to give complete lists of the Pacific islands where *Anopheles* are definitely known to occur. Both Edwards and Taylor omit from the range of *Anopheles* the Admiralty and Trobriand Islands, New Britain, New Ireland, the Santa Cruz Islands, and Samarai in the China Strait near New Guinea."

I would point out that neither Edwards (1932) nor Taylor (1934) is misleading in stating the distribution of *Anopheles* in the Pacific Islands. The localities given by us are political entities embracing all the islands under each designation, e.g., "Solomon Is." embraces all the islands and islets in the group which extends for 900 miles north-west and south-west, and north and south for a distance of 430 miles. It would be unreasonable for every island and islet to be listed by name. The Admiralty Islands, New Britain and New Ireland are all in the Territory of New Guinea; the Trobriand Islands and Samarai belong to Papua. The Santa Cruz Islands are under administration of the High Commissioner for the Pacific and are situated somewhat north of the Solomon Islands.

MALARIA IN BRITAIN.

"As already pointed out in Chapter III (p. 10), three of the four known British species of *Anopheles* are so common and widespread 'that the almost complete disappearance of ague (i.e. malaria) from England is only now commencing to be satisfactorily explained'.

"The inclusion, in an early part of this book, of some such comment in regard to British Anophelines was both obviously and regrettably necessary. Obviously—in order to dispose of the popular fallacy that 'there are, of course, no malaria-carrying mosquitoes in Britain', and regrettably because of the difficulty of considering, except at undue length, the complexities which this particular problem now presents as the result of the varietal subdivision of *A. maculipennis* (p. 119). It seems advisable, however, to direct attention—in the fewest possible words—to certain facts in this connection which appear to be not generally understood.

"Up to about sixty years ago, malaria—under the name of ague—was apparently as popular a topic of discussion in some parts of England as influenza is now; the polite enquiry 'Have you had your ague this spring?' being a periodically-recurring form of conversational opening.

"Unfortunately, knowledge regarding the regional distribution of malaria in Britain is far from being exact, owing to the fact (first pointed out by James) that the word ague (i.e. 'acute') used to be applied more or less indiscriminately to all kinds of disorders in which feverish symptoms were a conspicuous feature. It is beyond doubt, however, that in

certain parts of England—notably in the 'Fens' of Huntingdonshire and Cambridgeshire, as well as in many low-lying coastal areas of Suffolk, Essex and Kent—malaria used insidiously to undermine the health of the people. That this was the case in comparatively recent times is indicated by the fact that a great deal of information in this connection, derived from personal observation, has been supplied to the author by friends who are little older than himself. Most of this 'first hand' information is of an interesting nature. For example, there existed a widespread (and, as we now know, erroneous) belief that 'opium cured agne'. In the coastal districts of Essex, the remedies exhibited by the local chemist nearly always included an opened box of opium pills; the customer (apparently rather ashamedly) putting down the necessary number of pennies and helping himself. Opium pills were also sold for this purpose, within living memory, at Havant (Hants).

"The day is not far off, however, when the acquisition of first-hand information regarding 'malarious England' will no longer be possible. It seems probable that even in 1870, although indigenous malaria was then fairly common in England, signs of its gradual disappearance were already noticeable. There is no doubt that, in earlier times, the Fens were periodically visited by severe epidemics of the disease—the last recorded one occurring in 1859. Perhaps not long after the date of this catastrophe, the decline of the disease (owing to reasons which are discussed later) commenced.

"About twenty years ago, soldiers invalided home with malaria were often sent to convalesce in coastal districts of Kent and Essex where Anopheline mosquitoes were exceptionally prevalent, with the result that large numbers of previously healthy soldiers and civilians contracted the disease" (Marshall, 1938).

I have often been asked whether malaria occurs in cold countries. I have therefore added the above quotation.

PROTECTION AGAINST BITES OF MOSQUITOES.

"1. *Nets.*—The use of nets as a protection from the bites of mosquitoes has been practised from very early times. Ross (1911) notes that they were employed by the Romans, and were alluded to by Herodotus, Horace, Juvenal and other early writers. They still remain the most important of all measures of personal protection against the bites of mosquitoes. A mosquito net should always be used in any malarious locality, whatever other precautions may be adopted.

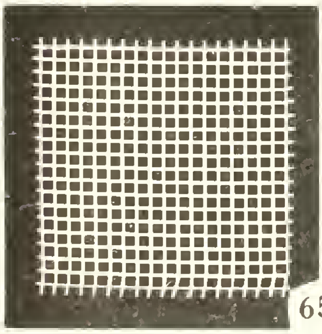
"The size of the openings in the netting is important, and this is determined not only by the number of holes to the inch, but also by the thickness of the cotton of which the netting is made. The mesh is stated in terms of the sum of the number of holes counted along a line of the warp and a line of the bobbin falling within an area of one square inch, the hole at the corner of the square where the two lines meet being counted twice (Fig. 66). Cotton is graded according to weight, and in terms of the ratio of the accepted factor of 840 yards to one pound. The mosquito netting supplied to the British Army in India is of 25/26 mesh, woven of 30's cotton. This means that the sum

of the holes counted along a line of the warp and a line of the bobbin in one square inch is 25 or 26, and that the cotton of which it is woven goes thirty times 840 yards to one pound (Macarthur, 1923). It does not mean that there are 25 or 26 holes to the square inch or linear inch of netting—in fact the number of holes to the square inch would be about 150. Netting of this type is however not infrequently misleadingly referred to as being of '25/26 holes to the square inch'.

"The material should be white, to allow of easy detection of mosquitoes. The top as well as the sides of the net should be of netting and not of calico, as the latter excludes air. The best pattern is the rectangular net, and the next best a bell net with a circular hoop a yard or two above the bed, to allow of the necessary stretching of the net. Not a single rent or hole in the net should be allowed, and there should be no openings in it for the purpose of entering the net.

"If possible a large bed and net should be used, so that the hands, knees and elbows may not be pushed against the net during sleep, and thus be bitten through it by mosquitoes outside. If these are not available, a loose valance of gauze or a strip of calico should be sewn round the lower part of the net for a height of about nine inches above the upper surface of the bed. The net should be made especially full at the corners, and it is an advantage to have webbing sewn diagonally across the top of the net to take the strain.

"The net should be hung *inside* the poles and tucked continuously all round under the mattress, and not be allowed to hang down to the floor. It should be let down before dark in the evening, and should be stretched as tight as possible in every direction to allow the air to pass freely through it. When going to bed a thorough search should be made for any mosquitoes which may be inside the net, preferably with an electric torch.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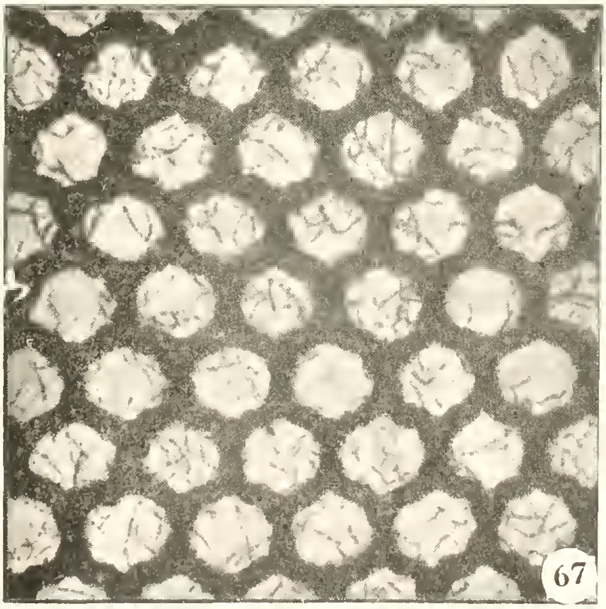
C.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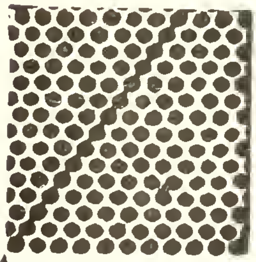
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66 B

Fig. 65.—Wire gauze 18 mesh and 33 gauge, actual size. Fig. 66.—Mosquito netting—26 hole mesh—actual size. Fig. 67.—Enlarged to show the fibrillæ.

The net should be put up in the morning by collecting the hanging portion together, twisting it into a coil and throwing it over the top bar of the frame."

The use of mosquito nets in the front line is as essential as a constant supply of ammunition. Mosquito nets can and have been used with marked success under most difficult situations. A sick man cannot fight, moreover he is an encumbrance.

"2. Mosquito boots are very useful to protect the ankles in the evening. These may be made either of soft leather, or of canvas. Wellington boots may also be used for this purpose.*

"3. Veils and gloves are sometimes used to protect men when on guard at night. Ross (1911) recommended the use of a hand-fan, an excellent substitute for which is a palm leaf.

"4. *Repellents or Culicifuges.*—The common drawback of all these is that after a certain length of time their effect wears off, but they have their value where men have to be out at night for limited periods in malarious situations. They are also useful for application when people are sitting out of doors during those sultry evenings which are so common in the tropics in the malaria season. Dover's preparation (1930) is particularly suitable. Its smell is not unpleasant, and it may be applied as a pomade to the hair to deter mosquitoes from biting the neck and face.

"The requirements to be aimed at are as follow:

(i) It must spread easily.
(ii) It must be of such consistency as to make it adhere strongly to the skin.
(iii) Its base must hinder the too rapid volatilization of the substances which it contains."

Dover's formula is as follows:

Oil of citronella	½ oz.
Spirits of camphor	¼ oz.
Cedarwood oil	¼ oz.
White petroleum jelly	2 ozs.

"Coogle (1923) in the U.S.A. noted that Anophelines were less numerous under railway bridges, the timbers of which had been treated with creosote oil, than under the neighbouring road bridges not so treated; and he recommended the application of creosote oil to the walls and ceilings of houses as a mosquito repellent. Fermi (1926), however, who tried this method in Italy reported that it was ineffectual.

"5. *Screening of Houses, Barracks, etc.*—The use of screening, especially where electricity is also available for light and fans, has made a great difference to the health and comfort of those who are able to occupy well-built houses in the tropics. It is, however, essential to screen not only sleeping quarters but also other living rooms, and more especially verandahs, and to provide, if possible, overhead fans in these also. Otherwise, the inevitable result will be that people will sit about outside the building in the hot weather till a late hour at night, probably with a large part of their persons exposed to the bites of mosquitoes.

* A pillow-case drawn up over the feet and legs is a useful precaution for ladies when dining. Joss-sticks (e.g., "Katol") may also be burnt under the table to keep mosquitoes away.

" In the case of troops it should be insisted on that the men go inside the screened barracks at sunset and remain there. If this is impracticable, strict orders should be issued that shorts must be replaced by slacks at sunset, and that either jackets must be worn or the sleeves of the shirt pulled down.

" The value of screening has been generally recognized for many years in America, Africa, Italy, and Malaya, in which countries it is extensively employed. During the last few years it has been introduced in the barracks of British troops in certain cantonments in India with excellent results. The following are the principal points to be observed :

" The building to be screened must be well built and in good repair.

" Door frames should be made of seasoned wood, with iron brackets at the corners, and should not sag on their hinges. A double wire attached diagonally across the lower half of the door and tighened up with a turnbuckle will tend to prevent this.

" No attempt at edge-fitting should be made. The door should be made to fit against a three-quarter-inch batten all round the inside, and sufficient space allowed for the door to swell in wet weather without scraping at the bottom.

" A light strip of wood should be nailed across the door frame at about the height of a man's shoulders. This is to push against when opening the door.

" There should be two fastenings for each door, one half-way up the top section and one near the bottom. The lower panel of the door may be strengthened by wire netting,* as a protection against kicks, and against dogs attempting to enter or leave the building. Doors should open outwards, so that any mosquitoes resting on them may be driven out when they are opened. They should be placed if possible on the windward side of the house, for mosquitoes tend to congregate on the leeward side. It is of great advantage to have double doors, with a porch or vestibule at least six feet in length between them. Strong springs should be fitted to the doors, to ensure that they shall remain tightly closed when not in use.

" Every aperture in the building should be screened. In the case of chimneys Coogle (1927) recommends the suspension of a wire cage containing naphthalene balls inside the chimney about two feet from the top. It may be mentioned, however, that Bunker and Hirschfelder (1925) state that mosquitoes appear to be indifferent to the odour of naphthalene.

" No removable screens or shutters should be used.

" No screening should be used within one foot of the floor, because it is liable to be damaged when the floor is scrubbed.

" No furniture should be placed against the screening.

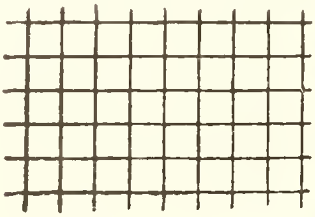
" Orenstein (1914) states that if copper gauze is used it should be fastened with copper tacks, and the rows of tacks covered by thin strips of wood, to avoid electrolization.

" As regards the type of gauze to be used for screening, there are several points to be considered :

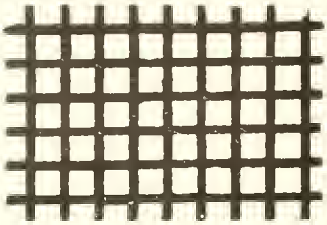
* If the gauze employed is of copper, the protecting netting should also be of copper and not of plain or galvanized steel, in order to avoid galvanic action. The aperture of the netting should be sufficiently small to prevent the ends of canes, umbrellas, etc., from passing through and damaging the gauze.

" (i) *Size of Aperture.*—As in the case of mosquito netting, the size of the openings in the screen is of the first importance. It is insufficient merely to state the number of openings to the linear inch, *because the size of aperture will vary with the diameter of the wire used.** It may be increased or reduced by 50 per cent. by the adoption of a thinner or thicker wire (Fig. 68). The diameter of the wire may be expressed by the number of the gauge, but unfortunately there are several different gauges in use, each of which denotes a different diameter of wire for the same number. Thus, Imperial Standard Wire Gauge (I.S.W.G.), No. 30, denotes a diameter of 0·014 inch. To avoid confusion it is therefore best to specify sizes of wire in decimals of an inch. Another source of confusion is that some authors in referring to size of aperture speak of the area in square inches, whilst others speak of the breadth of the opening in linear inches. The latter notation is the more usual, and will be adopted here.

" The gauze used in the barracks of British troops in India is of 14 mesh and 28–30 S.W.G., giving an aperture of 0·055 to 0·057 inch. The standard adopted by the Punjab Government, Public Works Department, is of 12 mesh and 25 S.W.G., giving an aperture of 0·063 inch. The size of aperture recommended by Messrs. Christie, Ltd., of Glasgow, for the screening of houses is 0·0408 inch (18 mesh and 28 I.S.W.G.). This gives a ventilation area of 53·93 per cent., as compared with 68·23 per cent. given by a gauze of 14 mesh and 30 I.S.W.G.



A



B

Two types of wire gauze. Both are of the same mesh, but the aperture of B is less than that of A by one-third, owing to the greater diameter of the wire.

Fig. 68.

" (ii) *Strength of Wire.*—It is obvious that, other things being equal, the greater the diameter of the wire used the stronger will be the gauze. It is equally obvious, however, that the use of a thicker wire will mean the exclusion of more air and light. Our aim therefore should be to obtain the thinnest wire which will give the required strength. The gauge usually recommended is 28–30 I.S.W.G., denoting a diameter of 0·0148 to 0·0124 inch, or 28–30 S.W.G., denoting a diameter of 0·016 to 0·014 inch. In order to obtain the greatest amount of air and daylight, a heavier gauze may be used in places subject to the greatest amount of wear, such as doors and the lower half of verandah screens, etc., a lighter type being employed for less exposed situations.

" (iii) *Durability of Screen.*—The material of which the gauze is made is of great importance. Painted† steel or

* The italics are mine.—F.H.T.
† It should be noted that painting reduces the size of the aperture.

galvanized iron wire are the cheapest, but are not suitable except in a very dry climate. Darling (1910) found that in a warm moist atmosphere galvanized iron and brass screening corroded rapidly, whilst copper and phosphorized bronze both resisted deterioration admirably. When tested in a salt-laden atmosphere, the copper screening also became badly corroded, the bronze resisting to a much greater degree. He therefore concluded that phosphorized bronze was best for places near the sea, but that for other places in the tropics the less expensive copper screening was just as effective, provided the copper content was high (about 90 per cent.), and the amount of iron as low as possible (not more than ½ per cent.).

"MacArthur (1923) recommends the use of 'Monel metal' as being the best for use in a moist climate. This consists of nickel 57 per cent., copper 28 per cent., other metal 5 per cent. It is a natural alloy of metals, and contains no tin, zinc, or antimony. A disadvantage of this is its high cost.

"The essential requirement for screening is that the work should be thoroughly carried out. Frequent inspection is necessary for the detection of rents in the wire and defects in the wooden framework, the latter being especially likely to develop where there is extreme variation in humidity between the dry and wet seasons.

"Measures Directed Against Adult Mosquitoes.

"1. *Destruction by Hand.*—This method has received increasing attention in recent years, and in view of the fact that recently fed and therefore possibly infected mosquitoes may be killed in this way, it has an important bearing in the prevention of malaria. Children may be taught to use the methods enumerated below.

"(*a*) *Hand-nets* may be made cheaply by tying a piece of flexible cane or wire in the form of a loop, to which a bag of white netting about 18 inches deep is attached. In lofty rooms a long-handled net may be used.

"(*b*) *Swatters* consisting of a piece of wire gauze about six inches square fixed to a two-foot wooden handle may be used, and are especially effective on wire screens.

"(*c*) *A chloroform tube* seven inches long by one inch in diameter may be used. A layer of rubber bands or pieces of old tyres one inch thick is placed in the bottom of the tube, held in place by a plug of absorbent cotton covered with a disc of blotting paper or cork. A few cubic centimetres of chloroform are poured in and are absorbed by the rubber. This will last for two or three weeks. A test-tube with a plug of cotton wool soaked in benzene or petrol may also be used, or a test-tube wetted inside with kerosene. To catch the mosquito, remove the cork and place the mouth of the tube quickly over the insect as it rests on some object. An electric torch is of great assistance.

"(*d*) A *tin* with some petrol or kerosene in the bottom, fixed to the end of a long stick, is useful in catching mosquitoes on ceilings.

"(*e*) Curtains, etc., may be shaken, and the mosquitoes flying out caught by hand, if the latter is first dipped in soapy water.

" The above methods may be used to supplement screening.

" 2. *Traps.*—The use of traps for catching mosquitoes was suggested by Nuttall and Shipley (1902), as the result of their experiments to ascertain the colour most attractive to mosquitoes.* Various different forms of trap have been devised, several of which are described below.

" Traps are used for three chief purposes : (i) for reducing the number of mosquitoes, (ii) to find out the relative prevalence of the different species of mosquitoes, and (iii) in order to gauge the effect of control measures. In the last two cases the traps are placed in various quarters of the area under observation, and counts are made of the mosquitoes captured in each trap daily. This is a valuable method for estimating the efficiency of anti-larval measures, and an increase in the catch in any particular locality will often lead to the detection of some breeding-place which would otherwise be overlooked.

" Traps may be used either inside or outside buildings. James' trap (1914) was designed for use in the shaded corner of a garden, and Zetek (1916) recorded that in camps where traps were placed on the lee side of buildings a large number of Anophelines were caught, resulting in a reduction in the incidence of malaria.

" When used inside houses, barracks, etc., the success of traps largely depends on the type of building in which they are employed. In well-built barracks with whitewashed walls the proportion of mosquitoes caught will be considerable, because the traps form a more attractive resting place than the bare white walls.

" (*a*) *Lefroy's Trap* (1907).—This is a wooden box twelve inches long by twelve inches wide and nine inches deep, lined with dark green baize, and having a hinged door. The floor of the box is covered with tin. The trap is set in a dark corner at night, and in the morning the door is closed and the insects killed by dropping a teaspoonful of benzene or chloroform through a small hole in the top of the box fitted with a movable plate.

" (*b*) *Fletcher's Trap* (1912).—This consists of a wooden skeleton of a box with a hinged lid, covered on all sides with black mosquito netting. This is contained inside an open-topped wooden box, painted black inside. The whole is placed in a suitable position at night, with the hinged top of the inner box open. In the morning the lid is closed with a metal hook fastener, and the inner box lifted out by handles provided for the purpose. The mosquitoes may be killed by placing this on the bare ground in full sunlight.

" (*c*) *Richmond and Mendis' Traps* (1930).—These observers have made a number of experiments with various traps of their own device in barracks. The most successful of these were :

(i) *The Crinoline Trap.*—A ' skirt ' of navy blue or black cloth with an upper opening four inches in diameter (which can be closed with a purse string) is suspended from the roof about six feet above the floor level. A bamboo hoop three feet in diameter is attached to the inside of the skirt two and a half feet from the top, and

* These observers found that dark blue was the most attractive colour, and it is suggested that this would probably be the most effective colour to use for the inside of the traps here described.

below the hoop the skirt is continued in the form of a fringe hanging vertically downward for a distance of three feet. The lower opening can be closed by a purse string, which runs through loops around the *outside* of the skirt (Fig. 69). At night the upper opening is closed, whilst the lower is left open. In the morning the lower opening is closed, and an inverted glass jam jar is inserted into the upper one. The trap itself is then well shaken, with the result that the imprisoned insects fly upwards towards the light into the jar, and can be removed alive.

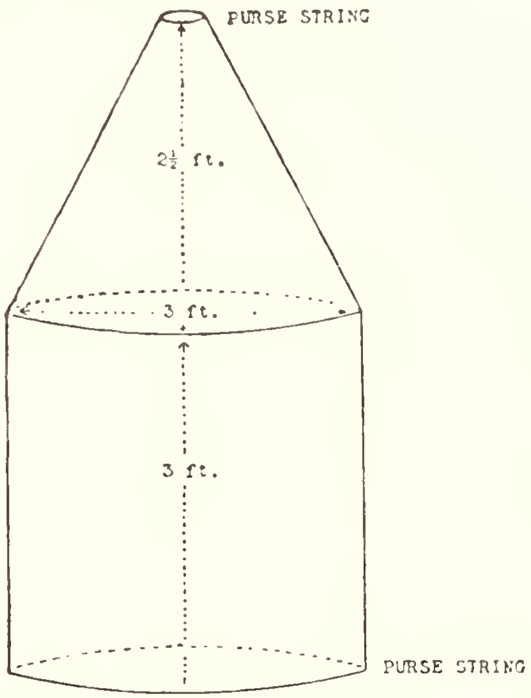


Fig. 69.—Crinoline trap. (*After* Richmond and Mendis, 1930.)

" If living mosquitoes are not required, the insects may be killed by simply spraying them with 'Flit' or other spray, without previously closing the lower opening."

Numerous other types of traps have been used for capturing mosquitoes, descriptions of which are to be found in the literature on the subject.

" *Fumigation.*—Which ever method is used, all chinks in the doors and windows should first be closed by hanging blankets over them. It is best to leave one window uncovered and to darken all the others. A white sheet is placed on the floor in front of the uncovered window. The reason for this is that in most cases mosquitoes are not killed by fumigation, but are only stupefied. They will for the most part fall on the sheet, and can then easily be seen, swept up and burnt.

" (*a*) *Pyrethrum Powder* (*Pyrethri flores*).*—This is made from the dried flower-heads of the chrysanthemum (*Pyrethrum cinerariæfolium*). It forms the main ingredient of many insect powders, e.g. 'Keating's Powder', and owes its insecticidal

* This must not be confused with *Pyrethri radix* (pellitory root), which has also been recommended as a fumigant.

activity to a mixture of acids and esters. It also contains oleoresins, to which it probably owes its value as a fumigant, and since these are volatile it is essential that the powder shall be fresh. It is also important to ensure that it is not adulterated with the powdered stems of the plant, which is a common practice.

"The powder may be used dry and puffed or blown into the air of a room. For fumigation it is heaped up in an iron pot into a little pyramid, which is lighted at the top and burns slowly, giving off a dense and pungent smoke. A layer of sawdust two to three inches deep placed in the bottom of the pot in the form of a crater permits complete combustion, thus saving 10 to 15 per cent. of the fumigant which would otherwise be wasted. The powder may also be moistened and made up into small cones, which burn readily when dry. One pound, at least, is necessary for 1,000 cubic feet of space [Boyce (1910) recommends 3 lb.]. The room should be kept closed for a period of three hours.

"Other methods are to heat the powder on a metal plate over a kerosene lamp, or to puff it from an insufflator into a burning gas-jet. The fumes are not noxious to human beings.

"(b) *Sulphur Dioxide.*—This may be applied in various ways:

(i) For operations on a large scale the use of a Clayton machine has proved most effective for destroying mosquitoes in yellow fever epidemics. Various types of Clayton machine are on the market. At Accra, a machine mounted on a bogey carriage is always kept ready for action. For treating ships, the machines are installed in special boats. There is also a light type of Clayton machine which can be carried by two men; it is air-cooled, and is capable of saturating 6,000 cubic feet of space per hour with a 15 per cent. strength of gas (Parsons and Brook, 1919).

(ii) It may be applied in the form of 'Sulphume', a proprietory preparation of liquid sulphur dioxide, put up in metal cylinders holding about 20 ozs. This was however not found very effective in a single experiment conducted by Parsons and Brook (1919).

(iii) Sulphur may be placed in an iron pot, and this placed on bricks in a tub or other receptacle containing an inch of water in the bottom. It is readily ignited by sprinkling methylated spirit or kerosene over it and lighting it. It is usually stated that 2 lb. of sulphur should be burnt for 1,000 cubic feet of space, with exposure to the fumes for two to three hours (but see below).

(iv) *Giles' Sulphur Cones.*—These consist of one part each of nitre and charcoal to eight of sulphur, made up into pastilles weighing 4 ozs. each by means of a little gum-water, and dried in the sun. Giles (1902) recommended that one pastille should be burnt for every 1,000 cubic feet of space, but this would only be equivalent to 3·2 ozs. of sulphur. Richmond and Mendis (1930) found that four pastilles (12·8 ozs. of sulphur) were effective in barracks for every 1,000 cubic feet of

space, whilst for fumigating tents six pastilles (19·2 ozs. of sulphur) were required per 1,000 cubic feet. Even this amount, however, is much less than the quantity of sulphur specified by other authors as necessary.

"Richmond and Mendis (1930) found the use of Giles' cones a very convenient method for sulphur fumigation. They are placed on tin plates on the floor, and when lighted burn quickly, producing a maximum concentration of sulphur fumes in a very short time.

"A great disadvantage of sulphur is that it tarnishes metal work, and injures pianos, sewing-machines, watches, telephones, etc. It is also harmful to foodstuffs.

Metcalf (MS. notes, 1939) writes:

"In the dry state sulphur dioxide is not a disinfectant and does not destroy spores and is not certain to destroy bacteria, but when combined with sufficient water vapour to form sulphurous acid (H_2SO_3) it becomes active and has some value as a surface disinfectant. From three to four per cent. of the gas after eight hours' exposure will destroy most if not all of the non-sporing pathogenic bacteria.

"The gas can be easily condensed to a colourless liquid by pressure and preserved in strong metal vessels. A pressure of about 45 pounds to the square inch is sufficient for this.

"In quarantine work it is extensively used for the destruction of rats, mice, fleas, mosquitoes, bugs, ants, flies, etc., on board vessels. It is useful to remember that most insects require a higher strength of the gas to destroy them than rodents do, and that the gas cannot be depended on to kill the eggs of lice, fleas, cockroaches, etc.

"On account of the heavy nature of the gas as compared with air, it diffuses slowly and then settles toward the bottom of the compartment. Its penetrating power is limited. The fact that it is heavier than air renders it difficult to clear out the fumes from the holds of a vessel within a short time.

"Sulphur dioxide may be obtained for fumigation work in several ways. By the burning of sulphur candles, the burning of sulphur in pots or pans, by liquid sulphur dioxide supplied in cans or tubes and by the Clayton method and its modifications.

"Sulphur gas has its greatest value in the holds of an empty ship when penetration and diffusion are not so essential. It is not nearly as effective if the vessel is laden with cargo owing to the difficulty of getting effective penetration.

"The methods adopted in Australian quarantine work are either the burning of the sulphur in pots or some modification of the Clayton process.

"*The Pot Method.*

"This method is the simplest, cheapest and probably the most efficient method of fumigating with sulphur dioxide. In addition it is applicable to vessels of all sizes. In practice the method cannot be expected to yield more than about 4 per cent. of gas, but this is more than necessary for quarantine requirements.

"The sulphur, cracked up into small pieces of suitable size, is put into flat iron pots or dishes. Not more than 25 to 30

pounds should be put into one pot. The pots should be sufficiently large so as not to allow the melted sulphur to overflow. As many pots as are necessary may be used. As the pots get extremely hot after they have been alight for some time, it is necessary in order to prevent burning of the woodwork of the vessel to place the pot in a large tub or pan of water supported, if necessary, on a brick. In cases where there is no woodwork and the pot rests on the steel or iron plates no water or frame is necessary.

"A properly constructed metal frame which supports the pot containing the sulphur and prevents it touching the floor is also in use. A second pot somewhat larger than the top one is attached to the frame underneath the one containing the sulphur. This prevents any overflowing sulphur reaching the floor.

"The water dish method is as a rule to be preferred as the presence of the water reduces the risk of fire should any of the sulphur overflow. Owing to the amount of heat evolved in the burning of the sulphur, water vapour is formed from the water in sufficient quantity to saturate the atmosphere.

"The presence of the water vapour increases the germicidal effect of the gas by the production of sulphurous acid.

"A little over three ounces of water requires to be evaporated for each pound of sulphur burned to produce this effect. This, however, is not essential for the dry gas is just as effective for the destruction of rats and insects. The destructive action of the gas on certain articles is due to the presence of sulphurous acid and sulphuric acid formed in the presence of water vapour.

"The sulphur is lit by making a small hole with the finger in the centre of the heap and pouring in a small quantity of methylated spirit to start the flame. Excess quantities of spirit are not necessary, and care should be taken to use only the minimum amount necessary to start the flame.

"This will as a rule not exceed more than a few teaspoonsful. The sulphur should be level in the pot to ensure a uniform burn out. Before lighting the sulphur care should be taken that all the bottles or tins of methylated spirit are well away from the flame, as accidents have happened through neglect of this simple precaution.

"With good quality sulphur there is not as a rule any difficulty in burning it. Unfortunately a great deal of the sulphur on the market is not always of high quality and various expedients have to be tried to get it to burn.

"One method used in Sydney has been found very satisfactory. Old bags are cut up into small parts about nine inches square. One of these squares is put into the bottom of the pot and the sulphur is placed on top of it. A small hole is scooped in the middle of the heap until the bagging is reached. The bagging is grasped at its centre by a small pair of forceps and is gently pulled up to the hole for a couple of inches. Methylated spirit is then sprinkled into the hole and on to the bag. It is then lit and it is found that the bag acts for a short time as a wick and the sulphur invariably burns right out. Any bituminous material is retained in the bagging.

"*Goods Likely to be Damaged or Spoilt during Fumigation with Sulphur Gas.*

"Sulphur dioxide cannot be used in many cases for fumigation purposes without the risk of doing considerable damage to goods in the compartment.

"The following summary shows the effect on many common articles:

Flour: The gas is readily absorbed and the flour rendered useless.

Wheat in bags is liable to be damaged, though wheat in bulk will not be seriously affected.

Meat, Vegetables, Fruit } Absorb gas and become unpalatable.

Frozen meat: Discoloured and dried up.

Tobacco: Spoilt.

Cigars: Crumpled up and rendered useless.

Cigarettes: Spoilt.

Soap: Ruined.

Tea, Coffee, Cocoa } Absorb gas and spoilt.

Matches, safety: Will not strike after fumigation.

Leather goods: Spoilt and damaged.

Sea boots: Spoilt and damaged.

Oilskins: Spoilt and damaged.

Rubber goods: Spoilt and damaged.

Manila rope, if wet, affected.

Metals: Tarnish.

Bronze, gilt and copper goods are tarnished.

Paintwork: Affected.

Vegetable oils: Absorb the gas, becoming brown.

Colours: Many are affected, particularly materials dyed with vegetable or aniline dyes.

Fabrics—cotton and linen: The action upon fabrics is not immediate, but manifests itself slowly, perhaps after laundering. It has a disintegrating effect on sugar bags, etc.

Upholstery and bedding: It leaves a disagreeable smell which clings tenaciously to these goods."*

"(*c*) *Cresylic Acid Derivatives.*

(i) *Cresol Vapour.*—This is probably the cheapest fumigant. Four to five ounces of Liq. cresol sap. are required per 1,000 cubic feet. It may be slowly vapourized over a kerosene stove of the 'Beatrice' type (in which the flame is guarded by a metal chimney with a mica window), the cresol being placed in some enamelled receptacle, which should completely cover the grating on which it rests; the receptacle should be as large and deep as possible, so long as its position is secure. Constant observation is necessary, and a bucket of water should be at hand in case the cresol should catch fire. The stove can be put out usually in about half

* Metcalfe, A. J., 1929: "Notes on Quarantine Procedure for Quarantine Assistants."

an hour's time (the time varies according to the size of the room and the amount of cresol used), after which the room should be closed for another $1\frac{1}{2}$ to 2 hours. It may also be evaporated in kerosene tins over charcoal braziers. The braziers should be glowing when put into a room, otherwise the fumes given off are liable to blacken the walls and furniture. Richmond and Mendis (1930) found that the cost of fumigating with cresol vapour, including the price of the charcoal used, was 1·65 annas per 1,000 cubic feet. Another method of vapourizing cresol is to ignite dung cakes and pour the cresol over them when half burnt.

"Although the cost of cresol fumigation is so low, the amount of preparation and precautions required for its use are much greater than in the case of sulphur. Opinions differ as to the relative efficiency of the two methods. Richmond and Mendis consider sulphur fumigation to be the more satisfactory, though the cost (about $3\frac{1}{2}$ annas per 1,000 cubic feet of space) is more than twice as great as with cresol.

"*Sprays.*—Experiments with various sprays as destructors of mosquitoes were carried out by Giemsa and Muhlens (1911), following the appearance of an article by Stendel (1911), who called attention to the neglect of this method of malaria prevention. Mixtures containing cresol and phenol were found too irritating to the human respiratory tract, and the same objection applied to solutions of quassiin. Finally Giemsa evolved a mixture containing pyrethrum tincture, soft soap and glycerin, which constituted an effective spray free from the above objections . . . The pyrethrum tincture was however expensive, and Giemsa (1914) conducted further experiments to find a cheaper spray. He found that soap solutions alone gave good results, and that the toxic properties of a number of other substances besides pyrethrum were enhanced by the addition of comparatively small quantities of soap. He recommended the use of soap solutions containing formaldehyde as being both cheap and effective.

"Giemsa's spray :	Parts
Pyrethrum tincture (20 parts pyrethrum extracted in 100 parts methylated spirits)	580
Potash soap	180
Glycerin	240

"The above mixture to be diluted with 20 volumes of water before use.

"One hundred grammes of the fluid suffice for 50 cubic metres of space.

"*Cutting Down of Jungle and Other Vegetation.*—Many species of Anophelines spend the daytime sheltering amongst long grass or in bushes and other coarse vegetation, and the clearing away of these in the vicinity of dwellings is therefore of value in the campaign against adult mosquitoes. (*a*) It removes the sheltering places of adult mosquitoes. (*b*) It promotes evaporation, and therefore the drying up of collections of water. (*c*) It discloses breeding places which otherwise may be overlooked.

"*Cultivation of Alleged Deterrent Trees and Plants.*—Eucalyptus trees, nim trees, chinaberry trees, castor-oil plants,

papaya, lavender, clover and various aquatic plants have been said to have a deterrent effect on mosquitoes, but experiments have proved that none of them have any direct effect against adults.

"*Zooprophylaxis.*—Animal prophylaxis against malaria was suggested by Roubaud (1919), although Rizzi (1919) claims that this method of protection was first recognized and practised in Italy. Roubaud pointed out that *A. maculipennis* only feeds on man in the absence of other sources of mammalian blood, and suggested that man could have complete protection from the attacks of this species by keeping cattle in the proximity of human dwellings. He stated that in regions where cattle were plentiful a race of these mosquitoes has evolved which have adapted themselves to feed exclusively on animals. Other authors have pointed out that whilst the presence of cattle may attract mosquitoes to themselves, the total population of Anophelines in a locality is largely increased where cattle are plentiful. There are also other factors to be considered, one being that the presence of large numbers of cattle goes hand in hand with increased agricultural prosperity, better drainage, clearing of jungle, and a betterment of the social and economic condition of the population, all of which may tend to diminish the incidence of malaria. It may further be pointed out that the presence of Anophelines in a cowshed does not necessarily mean that these have fed on the cattle occupying it. Numerous experiments by means of the precipitin test have shown how frequent it is to find human blood in mosquitoes caught in cattle byres, stables, etc., and, convesrely, to find the blood of cattle and other domestic animals in those captured in human habitations.

"Symes (1930) records that in Taveta, Kenya Colony, the women and children have for years lived in huts together with their cattle. The parasite rate is 50–60 per cent., and the spleen rate 85–100 per cent., whilst it is usual to find the majority of the malaria-carrying Anophelines close to the sleeping place of the human beings, in spite of the proximity of the fire, and the much greater accessibility of the cattle. He considers that the presence of the cattle in this region gives very little protection.

"Close association with cattle does not always prevent an epidemic of malaria. In the Punjab epidemic of 1908 the cattle zone of Amritsar city was one of the worst epidemic areas. Fry (1922) however points out that though those living in this zone suffered owing to the presence of cattle, the rest of the town was probably protected thereby from the abnormal mosquito population. He suggests that if cattle-sheds were arranged on the outskirts of a village instead of indiscriminately as is usually the case, the inhabitants would be more free from the attacks of mosquitoes.

"Fermi (1928) states that if animal prophylaxis is to be effective, the cattle sheds should be situated at a distance of 50 to 100 yards from human dwellings.

"MEASURES DIRECTED AGAINST THE LARVÆ OF MOSQUITOES.

"*Description of Methods Used.*

"Before describing the methods employed in dealing with larvæ, it is necessary to point out the *extreme importance of a*

careful preliminary survey of the area in question" (the italics are mine.—F.H.T.) "so that it may be ascertained which species of Anophelines are present, and where the breeding places of each are situated. Attention may thus be concentrated on measures to deal with the breeding places of the principal malaria carriers. For example, it is worse than useless to embark on expensive measures to drain a collection of water that may be harbouring either no larvæ at all or only those of harmless mosquitoes, whilst the less obvious breeding places of the malaria carriers are overlooked.

"Attention is also drawn to the fact that, when the favourite breeding places of any particular species have been eliminated, it will tend to breed in other situations, so that careful periodical inspections of the area concerned are essential.

"A point of great practical importance is the extent of the area over which it is necessary to practise anti-larval measures. No strict rules can be laid down on this point, for a great number of factors must be taken into consideration, and the final decision will depend on a close study of the local conditions prevailing, such as the species of malaria-carrying Anophelines concerned, the intensity of breeding, the direction of the prevailing wind, etc.

"As a general rule . . . anti-larval measures should be undertaken for a distance of at least half a mile from the periphery of the area to be controlled. This may have to be extended in certain directions if breeding of malaria-carrying Anophelines outside this radius is very intense, or if there is a strong prevailing wind from a particular quarter. On the other hand, it may not always be necessary to undertake rigid control measures for half a mile in *every* direction. Thus, Senior-White (1928) obtained excellent results by instituting anti-larval measures for a quarter-mile radius round certain camps in a very malarious area in the Vizagapatam Agency (Madras Presidency, India), where a railway was being constructed, the area being extended in one direction nearly three-quarters of a mile from the centre of the main camp on account of the prevailing wind.

"On the other hand, Hackett (1929) in Italy has found it necessary to control mosquito breeding for a distance of three kilometres (nearly two miles) from the periphery of the area requiring protection.

"Many experiments have been carried out with a view to ascertaining the distance of flight of Anophelines, and it has been shown that on occasions certain species will fly for distances of several miles. But, in considering the size of the area over which it is necessary to practise anti-larval measures, it must be remembered, as Ross (1911) has pointed out, that it is not a question of the power of flight of Anophelines, or how far they *can* fly, but how far they actually *do* fly *on the average*.

"In instituting control measures much useful information may be obtained by the use of 'catching stations' or 'observation stations'. Certain shelters are selected in various quarters of the camp, village or other locality which is to be protected. These are visited regularly (daily, if possible, during the first season of control), and the same collector catches as many adult Anophelines as possible in a given time, say 15 minutes in each spot. Or, traps may be placed in selected places, and the

catches collected daily. In this connection C. J. Wilson (1930), as a result of experiments with a specially constructed trap made with mosquito netting in the Federated Malay States, came to the conclusion that the result of trap catches was more valuable as an indication of the species of Anophelines frequenting dwellings than the results of catches by collectors.

"A record is kept of the number of each species taken in each catching station. This is a most valuable means of testing the efficiency of control measures, and will frequently lead to the detection of some breeding place which would otherwise be overlooked.

"After the usual preliminary malaria survey has been carried out, the following procedure is suggested :

"(i) First select catching stations, one at least being situated on each side of the area to be protected. Regular catching should preferably be started at least six weeks before the beginning of the malaria season. Indeed, it would be better still if catching and other observations could be carried out for one complete season before instituting control measures ; but this is seldom possible in practice.

"(ii) Institute rigid anti-larval measures over all actual and potential breeding places of malaria-carrying Anophelines for a distance of one-quarter of a mile from the periphery of the area to be protected. Control measures should be initiated *before* the annual increase in the numbers of adult malaria-carrying Anophelines occurs, i.e. usually about one month before the commencement of the malaria season.

"(iii) If any particularly dangerous breeding places, such as a ravine stream or seepage outcrop, exist between the quarter-mile and half-mile radius, control these also.

"(iv) Scrutinize the daily records from the catching stations. The capture of a considerable number of malaria-carrying Anophelines in any particular catching station may indicate that control measures must be extended in that direction beyond the half-mile radius (probably in the direction from which the prevailing wind is blowing) or that some particular breeding place has been overlooked.

"Our aim is of course to control the smallest possible area that will give good results. Every hundred yards added to the radius of the controlled area means a large increase in expenditure. It is usually found that expenses incurred in anti-malaria measures during the first year can be very considerably reduced during subsequent malaria seasons. It may for instance be found that all the malaria-carrying Anophelines are breeding in some particular part of the area, and attention can then be mainly directed to these special places.

"Temporary measures, such as the application of paris green, oil, etc., should be discontinued at the end of the usual period of the malaria season in the particular locality concerned. To continue them after this date will merely, in the author's opinion, result in a useless expenditure of labour and money.

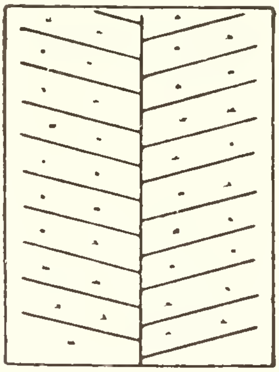
"Other things being equal, permanent measures, i.e. the complete abolition of breeding places, should be adopted wherever possible. Temporary measures, such as oiling, etc., should only be employed (*a*) when the cause of breeding is temporary (e.g. during the construction of docks, railways, etc.),

or (*b*) when the cost of permanent measures is prohibitive. It may be remarked here that permanent measures, although they may involve a greater initial outlay than those of a temporary nature, frequently prove more economical in the long run, owing to the constantly recurring expenses of the latter, and the necessity for maintaining a large inspecting staff.

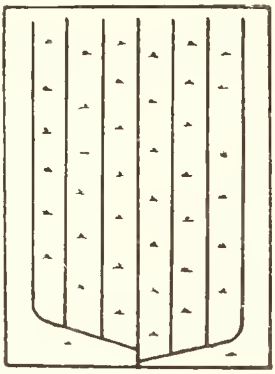
"A word of warning on this subject is however necessary." Certain dangerous malaria-carrying *Anopheles* prefer breeding in places exposed to bright sunshine, e.g. *Anopheles punctulatus* and *A. punctulatus* var. *moluccensis*. "The indiscriminate clearing of jungle in places where such species exist may therefore be followed by disastrous results. This occurred in a district in the Federated Malay States, where the wholesale clearing of jungle, though proving inimical to the shade-loving *A. umbrosus*, provided excellent breeding places for the more dangerous *A. maculatus*.

"*Open Drains.*—These should be narrow and deep rather than broad and shallow; their banks should be kept clear of vegetation and sloped to an angle of about 45 degrees; tributaries should enter at an acute angle or curve where possible, and not at right angles, in order to lessen the deposition of silt and debris at the point of junction. The bottom of the drain should be rounded, and not V-shaped.

"In dealing with swampy areas drains may be made either parallel with one another or arranged in 'herring-bone' fashion. The former method is the more economical. For example in draining an area of 14 acres with lines of drains laid 100 feet apart, the herring-bone system would require 300 feet more of drain than the parallel (King, 1922. Fig. 70.) In the case of hill-foot seepages the best method is to construct a system of 'contour' drains, to catch seepage at the point at which it arises.



A



B

Fig. 70.—Two systems of laying out drains, in areas of equal size. In both the drains are the same distance apart, but the length of drain in A is considerably greater than in B. (*After* King, 1922.)

"*Hill-foot Seepages.*—These are best treated by constructing a system of hill-foot contour drains, to catch the seepage at the point where it arises. These may be either open or subsoil drains; if open, regular oiling will be necessary. Occasionally it may be possible to deal with seepages on the banks of a ravine

stream by damming the ravine and submerging the springs (Knowles and Senior-White, 1927).

"Drains should be as few and as short as possible, and the fall of the ground should be carefully considered before commencing work. The excavation for drainage should start at the outfall end. Sharp bends should be avoided wherever possible. The main drain should be constructed first, and the tributaries afterwards. In some cases the use of dynamite has been found helpful in the construction of drains (Base *et al.*, 1919).

"Open drains may be either 'pukka', i.e. lined with concrete, brick, stone, etc., or 'kuchcha', i.e. open earth-drains. A pukka drain should never be constructed without first making a kuchcha one to determine the requisite depth of the drain, and to see whether the flow is satisfactory.

"Pukka drains should be made with a central deeper channel or 'cunette', to take the water along quickly when its level is low, and to minimize the extent of the breeding area. At the point of junction with a side channel the opposite side of the drain should be strengthened and raised to prevent overflow. 'Weep-holes' should be made in the side of the drain so that the subsoil water may get into it. These should slope downwards towards the bottom of the drain. It is also an advantage to construct 'key-walls' at right angles to the drain at intervals, especially where there is a curve in its course, to prevent water from outside tearing away the earth supporting the side walls (Fig. 71). Key-walls should extend six inches to

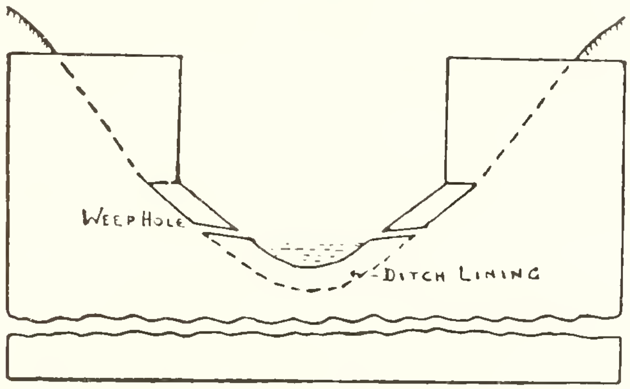


Fig. 71.—Cross section of key-wall. (*After* Le Prince, 1915.)

a foot or more into the ground below the bottom lining of the drain, and in all cases weep-holes should be provided just above the key-wall. In wide drains the side walls may be almost vertical.

"It is not always necessary to line the entire drain, the lining of the bottom and sides up to three inches above the normal water line for small ditches being sufficient as a rule. A drain may be roughly lined with flat stone, the interspaces being filled in with small stone and sealed roughly with cement mortar. Where flat stone is not available concrete made with gravel or small stone, in a layer of about two inches in thickness and reinforced with two-inch mesh wire netting, may be used.

"In places where a drain has to pass beneath a road by means of a culvert, the grade of the drain should be increased, to

prevent the accumulation of silt or debris. The bottom of the culvert should be lined with stone or concrete. A screen of vertical rods may be provided at the entrance of the pipe or culvert, and in the case of an earth drain the bottom should be lined for a distance of about six feet with flat stone or timber at the point of discharge, so as to prevent erosion and the formation of a pocket.

" In the case of kuchcha drains, if the flow of water is very swift undermining of the banks may occur, or if there is some temporary obstruction excessive local scouring may ensue, removing soil from below the grade line of the bottom of the drain, and causing a ' pot-hole '. Subsequently, if the rest of the drain becomes dry (as in stormwater drains), pools will remain in such situations, which may become Anopheline breeding places. A small temporary channel should then be made to connect these pools and drain off the water. It is sometimes possible to effect this rapidly in the case of a drain with a muddy bottom by dragging a small log downstream in its bed.

" The necessity for repeated re-grading, cleaning and oiling of open earth drains makes their upkeep expensive. They are of no use in localities subject to very heavy rainfall, as when this occurs the system will be wrecked. Lined drains last much longer, are more easily cleaned, require less inspection and are frequently ultimately less costly than open earth drains (Prince, 1915).

" *Subsoil Drains.*—The drain in this case is formed by a series of unjointed tile pipes laid end to end close together in trenches beneath the ground, the water entering from below at the points of junction of the pipes. If soft spots are found in the bottom of the trench (which must of course be properly graded), stones are rammed into place until a solid foundation is obtained. Kligler (1925) has found it useful where gravel is available to lay the tile pipe on about 10 cm. depth of gravel, and to cover it with 10–20 cm. of the same material. He has found that in pipes so laid clogging has been negligible, whilst in others it is of periodic occurrence. The laying of the pipes should be commenced at the outlet of the drain, and continued upwards as the trench is made. In fine, easily disintegrated soils, the pipe joints should be covered with a wrapping of

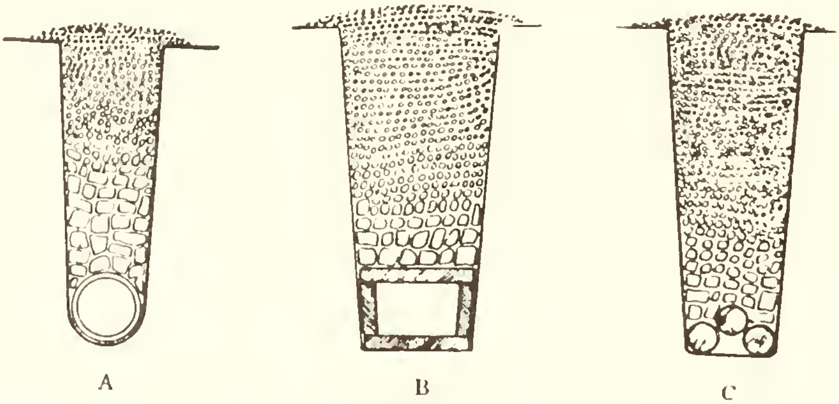


Fig. 72.—Cross-section of three types of subsoil drains.
A. Tile drain. (*After* Le Prince, 1915.)
B. Stone drain.
C. Pole drain.

canvas, palm leaves or other material, to prevent clogging. The pipes should be of circular bore, from three to twelve inches in diameter and one to two feet in length. As a rule the internal diameter of the pipes should not be less than four inches, even for hill-foot drains, whilst main drains are usually from six to eight inches in diameter. Where more capacity is required two or more drains may be laid side by side. The thickness of the drain should be three-eighths of an inch for pipes of three or four inches in diameter, half an inch for those of six inches in diameter, and five-eights of an inch for those of eight inches in diameter. It is impossible to lay down rigid rules for the capacity of the system, but in general it may be said that the pipes are calculated to run not more than one-quarter full (one-fifth for main drains over six inches in diameter) during ordinary dry weather (at least two or three days after moderate rainfall), they will be sufficient to do their work during floods (Evans, 1916). The pipes should be laid in an absolutely straight line, with as few changes of gradient as possible.

"Greasy water and house waste must not be allowed to discharge into any part of the system. Where pipes come near the surface, proper bridge crossings are necessary, to protect them from being crushed by carts, etc. The outlet of the subsoil drain must be well above the high water level of the stream, lake or ditch into which it discharges. Inspections should be made to see that the outlets do not become clogged with silt or other deposit. Metal rods placed vertically at the outlet will prevent the entry of small animals which might die in the pipes and cause blockage.

"Subsoil drainage in connection with mosquito control is used for the following purposes:

(i) To lower the ground water so that pools of surface water will be more readily absorbed.
(ii) To intercept seepage.
(iii) To deal with hill streams in ravines.

"(i) Where this method is used for lowering the subsoil water the lines of pipes are usually spaced from 50 to 150 feet apart. They are generally laid from two to four feet deep. If laid nearer to the surface the water is drained away more rapidly, but the area drained is less extensive. The pipes are laid in the bottom of a perfectly graded narrow trench, with their ends abutting one another closely, and are then covered with clay or earth. A grade of one foot or more per 400 feet is desirable (Prince, 1915).

"(ii) To intercept seepage the drain is constructed above the line of outcrop at the time of maximum flow, approximately at right angles to the flow, deep enough to collect the seepage, and with a grade of not less than one foot in 200 feet. The pipes are laid with open joints, or about one-eighth to one-fourth inch apart, and the trench filled with stones. The uppermost layer should be of small sized stones, and should extend two or three inches above the surface of the ground (Prince, 1915).

"(iii) In dealing with hill streams in ravines, it is necessary that the pipes should be buried *at least* three feet deep. The pipes should be covered by a layer of heavy stone, the smaller stones being placed above as before, but in order to prevent silt

from reaching the pipes and blocking them, it is necessary for the topmost layer itself (i.e., the floor of the ravine) to be of silt. In wet climates a layer of grass will grow over this, and will prove efficacious against scouring. It is most important that trees growing within a distance of some 40 feet from the pipes shall be rooted out, otherwise their roots will grow down into the pipe junctions and block them.

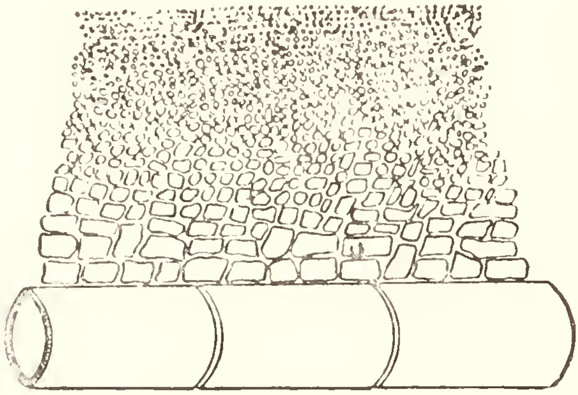


Fig. 73.—Subsoil tile drain, longitudinal section.
(*After* Le Prince, 1915.)

" The advantages claimed for subsoil drainage, as compared with open drains, are that it is self-cleaning, maintains itself, permits of rapid inspection, needs very little attention, requires no oiling, and permits of no exposure of water accessible to mosquitoes. It should be pointed out, however, that the laying of pipes should, as a rule, only be undertaken by a skilled engineer. Its principal disadvantage is its cost, which is a grave objection, especially when dealing with ravine streams. Senior-White (1927) remarks that in the case of streams which run only for two months or so after the slackening of the monsoon, oiling is probably more economical.

" Where stones are not available, larch or other poles may be laid lengthwise in the bottom of the drain, one on each side and one on the top, forming a conduit (Fig. 72).

" Another method is simply to make deep trenches and fill them with stones, but in this case it is necessary to dig them up and clean out the silt at intervals.

" *Vertical Drainage.*—This may prove a useful and economical measure, especially in the case of swamps and marshes. The bed of the marsh is probably of silt or clay, which retains the water, but underneath this there may be a permeable or fissured rock which will give drainage. In order to drain the marsh a pit is sunk down to the permeable rock, the exposed surface of which is blasted. The pit should be filled with rock filling, a vertical line of pipe being carried to the level of the marsh bottom. The pipe should be surrounded with stone or gravel. Spigot and socket sewer pipes or iron pipes coated can be used, or a circular pit built up in stone masonry. A circular strainer should be put in round the mouth of the sinkage (Home, 1926). Probably several of these pits will be necessary if the marsh is a large one. A certain amount of

grading will be required in the marsh leading to the sink-holes (Fig. 74).

"*Oiling.*—The use of oil to diminish the number of mosquitoes was recommended in a note in *The American Advertiser*, Philadelphia, in its issue of August 29th, 1793 (McFarland, 1928). It was also suggested in a work entitled 'Omniana Otiosores', said to have been written by R. Southey, which was published in London in 1812. The first published account of scientifically conducted experiments with oil as a mosquito larvicide appears to have been that of Howard, which appeared in 1892.

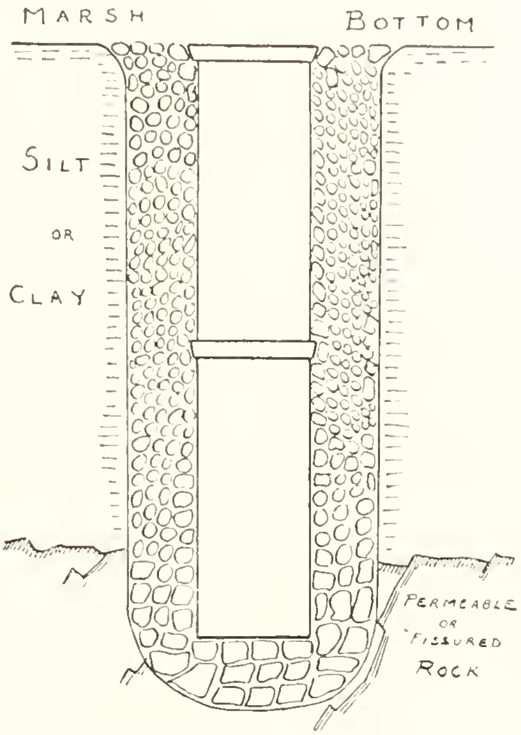


Fig. 74.—Vertical drainage. (*After* Home, 1926.)

" *How Oil Kills Mosquito Larvæ.*

" It was originally supposed that the lethal effect of oil on larvæ was due solely to the fact that it suffocated them by cutting off their air supply. A great deal of investigation has since been carried out as to the manner in which oil kills larvæ, the various theories put forward being as follows:

(i) Suffocation of the larvæ by producing a surface film which cuts off their supply of air.
(ii) Blocking of the respiratory tubes by particles of oil.
(iii) Toxic action of oil vapours.
(iv) Toxic action of the oil directly by contact.
(v) Toxic action of the oil indirectly by solubility in the water.
(vi) Reduction of the surface tension, making it difficult for the larvæ to remain at the surface, and thus causing them to 'drown'.

" Freeborn and Atsatt (1918) found that the toxicity of oils increases with their volatility, and that the volatile constituents contain the principles which produce the primary lethal effect;

but that in the case of those oils with negligible volatility (boiling point over 250° C.) the lethal action may be due either to blocking of the respiratory tubes, poisoning by contact, or even by suffocation. They did not consider that the reduction of surface tension or toxicity from solubility in water had any effect.

" More recent researches have in the main confirmed these observations. Green (1924) showed that the rapidity with which larvæ die depends on the volatility and toxicity of the oil, that the larvæ obtain their fatal dose of oil in a very short time (less than one second with petrol, and within one minute with an absolutely non-toxic oil, Nujol), and that *Culex* larvæ take a very much longer time to die than *Anopheles* (six to eight times as long).

" Oil also tends to deter the adults from depositing their eggs, whilst it kills the algæ, forming with them a dense floating mass which probably has a deleterions effect, and in any case reduces the food supply of the larvæ. In its place there appears a closely felted alga attached to the stones or sand forming the bed of the stream or pool, the presence of which forms a useful indication as to whether oiling has been carried out effectually (Watson, 1921).

" *The Spreading Power of Oils.*

" The spreading of oils, however, does not depend on viscosity, and a thin oil does not necessarily show better spreading powers than a thick. Ginsburg (1927) has shown that the tar acids having hydroxyl (OH) groups (e.g., phenols, cresols, xylenols), increase the spreading power of mineral oils, as also do the monohydric alcohols, pine oil and turpentine. Cresols and xylenols proved more efficient than the other compounds, the addition of one gallon of crude cresol containing 95 per cent. cresylic acids to 100 gallons of fuel oil greatly increasing the spreading and penetration of the oil on salt and fresh waters covered with dead organic matter and vegetation. In laboratory experiments it has been found that the addition of 1 per cent. cresol to fuel oil increases the spreading power by 50 per cent. The duration of the oil film is also appreciably increased by this treatment.

" The addition of small quantities of a vegetable oil also greatly increases the spreading of mineral oils. According to Hacker (1925) vegetable oils probably spread by virtue of the free fatty acids which they contain. Leak (1921) recorded that the addition of 1 per cent. of castor oil to kerosene increased the spread 25 times. He found that 2 ozs. of kerosene covered an area five yards in diameter, whilst on the addition of 1 per cent. of castor oil an unbroken film 30 yards in diameter was found.

" The presence of dust or grease on the water, or of soap or soapy material in the water, prevents oil from spreading, and this has to be taken into account when considering the amount of vegetable oil, etc., to be added. The presence of grease or soap explains why an oil which may give excellent results on natural waters will often lie in patches when applied to water containing drainage from dwellings.

"*The Choice of Oil.*

"There are many grades of oil on the market which may be used for mosquito destruction, ranging from the very light oils such as kerosene to the heavier forms known as crude oils. The choice of an oil will depend very largely on local conditions; thus, with high temperatures a thick oil is required, whilst in the presence of vegetation an oil with great spreading power is necessary. Again, in the case of still water a heavy non-toxic oil applied in sufficient quantity to form a complete film will after some hours kill all the larvæ; whilst in the case of moving water a thin layer of rapidly spreading oil with a high toxicity is indicated.

"As already stated, the poisonous action of mineral oils is related to several factors—viscosity, volatility, and the presence of aromatic hydrocarbons or of certain natural poisons. A thin oil will enter the breathing tubes of the larvæ quicker than a thick, whilst, as we have seen, a high volatility and a high percentage of aromatic hydrocarbons increase the lethal effect. Unrefined oils, such as fuel oil or diesel oil, contain small quantities of substances (organic acids, nitrogen and sulphur compounds), which appear to exert a poisonous effect. These are partly removed by refining processes, and a highly refined lubricating or paraffin oil will therefore prove less poisonous than a black fuel oil of the same thickness.

"(*a*) *Kerosene Oil.*—This may be applied alone, but there are certain objections to its use:

(i) The film is so thin that a very slight disturbance of the water surface by floating debris, projecting vegetation, ripples caused by the wind or current, etc., break the continuity of the film.

(ii) It is expensive, and likely to be stolen by unscrupulous employees.

(iii) It is transparent, and therefore likely to be wasted by the persons applying it, because it is difficult to see whether the film is satisfactory.

(iv) There is risk of fire, e.g. where sparks from a passing railway train may drop into it.

"(*b*) *Crude Oil and Other Unrefined Oils.*—The 'liquid fuel' of the petroleum companies is not, properly speaking, crude oil, but a refuse after some of the more volatile oils have been distilled off. Its composition varies considerably in different consignments. Watson (1921) notes that some consignments can be used alone, whilst others need the addition of one part of kerosene to eight parts of liquid fuel before use with a sprayer. The dark tarry solution of extractives which is found at the bottom of the oil drums is toxic to larvæ, and is very useful for application in springs, etc. The addition of from 1 to $2\frac{1}{2}$ per cent. of a vegetable oil, castor, coconut or whatever kind may be available locally will increase the spreading power of crude oil or liquid fuel to a great extent, castor oil being the most effective.

"Kligler (1925) in Palestine found that the most effective mixture was one part of crude oil to four parts of kerosene with from 0·1 to 0·2 per cent. of castor oil added.

" Williamson and Rajamoney (1928) suggested the use of a mixture containing equal parts of crude oil, solar oil and rubber oil. Rubber oil does not increase the spreading power of the other two, but greatly increases their toxicity. Solar oil, a heavy fuel oil derived from aromatic crude oils, probably imparts continuity to the films, whilst the inclusion of crude oil is justified on account of its low cost, and the fact that it evaporates less quickly than either of the others, thereby prolonging their continuance on the water surface.

" *Anti-malarial Oil* (A.M.M.) is a mixture containing diesel oil, solar oil and kerosene, put up by the Asiatic Petroleum Company. Diesel oil is unrefined and non-volatile at ordinary temperatures and is added to give a lasting effect. Poisonous substances also occur naturally in this oil.

" *Waste motor oil* (' crank-case oil ') has been tried extensively in America. Peterson and Ginsburg (1929) note that this usually needs straining and does not spread on water, but may be made to do so by adding a tar acid containing 25 per cent. cresylic acid, or by adjusting the specific gravity to 32 or 34 Be. by adding light petroleum distillates. They state that the lasting quality of the oil mixture is two to four weeks, twice as long as that of fuel oil, and that the cost is only half that of the latter. Walch and Bonne-Wepster (1929) also used waste motor oil, and found it effective when mixed with 10 per cent. kerosene and 1 to 2 per cent. coconut or castor oil, 10 to 20 c.c. of the mixture being applied per square metre of surface. They also obtained good results with a mixture of three parts waste oil and one part solar oil. Waste crank-case oil destroys vegetation.

" Barnes (1925) has found a mixture of nine parts of crude oil with one of pine oil effective. The latter, which contains various alcohols and ketones, has a powerful soporific or paralysing effect on the larvæ, and also increases the spreading power of the crude oil.

" *Methods of Applying Oil.*

" Spraying by means of a spray-can or knapsack sprayer. By this means the oil can be distributed to a distance of 20 to 30 feet from the operator. The sprayer when filled must not be too heavy, a pattern with about 2½ gallons capacity being suitable . . .

" The oil should be filtered into the sprayer through a sieve (which is usually supplied with the machine), and after each day's use the apparatus should be washed out by pouring a pint or so of kerosene into the container, and blowing it out through the nozzle by pressure. All spraying requires supervision by some intelligent individual, whose duty it is to see that the jets do not get blocked, and to re-pack joints and valves (1927).

" *Balls or ' guddas '* (pillows) may be made of tow or sacking, weighted with stones, and thrown into pools, etc., after being soaked in heavy oil. The oil oozes out gradually and comes to the surface. A better plan is to have them attached to a float (made by sealing up an empty tin), so that they do not sink to the bottom (Fig. 75). This prevents the collection of silt round them, which eventually makes them ineffective. This may

be placed in drains, or tethered along the edges of streams, irrigation channels, etc. They should be opened out and dried at intervals of seven to ten days, and re-soaked in oil. It is also well to shake them every two days or so, without removing them from the water. A 'gudda' shaped like an ordinary pillow, 28 inches long and 16 inches broad, made of sacking, will soak up about two gallons of oil at first, and about one gallon when re-soaked. It will last about three months. Oil balls may also be dragged along drains like mops, thus clearing the drain, and at the same time oiling it.

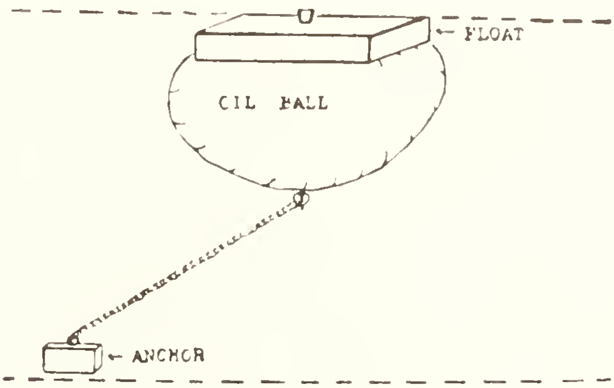


Fig. 75.—Oil ball and float.

"Oil may be mixed with *sawdust* and thrown after the manner of sowing grain. The mixture must not be wet to the touch, and the particles must separate cleanly when thrown on to the water. The best results are obtained when the mixture is allowed to stand for 24 hours before use. This method has been advocated for use among vegetation. The proportions to be used are roughly 30 gallons of oil with 10 bushels of sawdust per acre (1921)."

A sugar bag filled with sawdust which has been thoroughly impregnated with fuel diesel, crude, or sump oil, the neck fastened and tied to a stake driven into the ground at the head-waters of a creek, is very useful. The condition of the oil film on the water gives warning when it is necessary to renew the sawdust.

"*Drip-cans* may be used for the automatic oiling of streams and drains. They may be used as follows:

"(*a*) A nail may be knocked through the bottom of the receptacle, and a piece of wool wrapped round the head of the nail. By pulling on the latter the flow may be regulated.

"(*b*) A tap may be fitted to the receptacle.

"(*c*) A thick lamp wick may be stuffed into a hole near the bottom of the receptacle.

"The amount of oil allowed to drip suggested by Le Prince (1915) is 10 to 20 drips per minute for a water surface one foot wide.

"The disadvantages of oil drip-cans are that they do not give good service without proper attention, and may get clogged or be washed away by floods, or be stolen.

"*Amount of Oil to be Applied.*

"It will be evident from what has been said above that the amount of oil necessary to control mosquito breeding will vary very greatly according to the local conditions obtaining, i.e., climatic conditions, presence or absence of vegetation, kind of oil or mixture of oils employed, etc. However, as the question is so frequently asked in connection with the probable cost of anti-larval measures, it may be laid down that half an ounce of oil per square yard of water surface, or 15 gallons per acre, is usually an ample estimate. It is claimed for some of the proprietary preparations that very much less than this is needed. The exact amount of oil required in any particular case can only be ascertained by actual trial in the field.

"*Frequency of Oiling.*

"It is usually said that oiling should be repeated every ten days, but in practice it will be found more effective to oil at intervals of seven days. This is not because such a practice is essential to control breeding, but because unless it is definitely laid down in the programme that such and such breeding places are to be oiled on a specific day of each week, it is inevitable that certain places will be missed. Like everything else in connection with malaria prevention, the success of oiling depends on the thoroughness with which it is carried out. Oiling should not be attempted in drains or streams during heavy rain. Should a heavy downpour occur within an hour after oiling, the process may have to be repeated.

"*Tests of Thorough Oiling.*

"Apart from the absence of living larvæ, two other tests of the efficiency of oiling may be mentioned :

(i) The marginal vegetation along a properly sprayed drain should be burned brown for a foot on each side, and after a few applications bare earth margins should become exposed.

(ii) In regularly oiled drains *Spirogyra* will disappear and be replaced by a bottom growth of a matted Cyanophylaceous alga, which, as pointed out by Watson (1921), is correlated with the absence of mosquito larvæ.

"*Where Oiling is Applicable.*

"Oil may be applied in the case of pools, drains and streams . . . lakes and rivers, and wherever it is necessary to destroy Culicine as well as Anopheline larvæ, provided that the water is not to be used for drinking or domestic purposes. It is especially applicable to temporary collections of water which are too numerous to drain, or to control breeding places while steps are being taken to deal with them by permanent measures.

"*Disadvantages of Oiling.*

"(i) Oil will not easily penetrate a barrier of grass, and to make it thoroughly effective all vegetation and floating debris should be removed.

(ii) Wind will break up an oil film, and will carry the oil to one side of a sheet of water.

(iii) During rainy periods the value of oiling is decreased. Showers of rain wash away the oil.

(iv) Oil is heavy for transportation.

(v) It may kill fish, and renders them unfit for human consumption.

(vi) It renders water unfit for drinking purposes.

(vii) It is likely to deter mosquitoes from depositing their eggs, thus driving them to other unoiled collections of water.

(viii) It is likely to be stolen by unscrupulous employees.

" *Advantages of Oiling.*

" (i) Oil kills the ova and pupæ of mosquitoes, as well as the larvæ.

(ii) It kills Culicine as well as Anopheline larvæ.

(iii) It is easily obtainable everywhere.

(iv) It is easy to see whether it has been properly applied.

(v) No elaborate apparatus is required for its application.

(vi) Its use, though requiring supervision, does not involve the amount of supervision as does, for instance, that of paris green.

" In India, *Malariol*, a proprietary preparation specifically designed for anti-larval purposes, is now widely used, and has been adopted by the Army authorities. It is claimed that this oil has good spreading powers, is highly toxic to larvæ (killing them within 15 minutes of application) and burns up the vegetation and grass amongst which the larvæ shelter along the banks of breeding places to which it is applied. It is, however, somewhat more expensive than the diesel oil-cresol mixtures formerly in general use, and opinions differ as to whether the advantages claimed for it compensate for the increased cost. One decided advantage of this preparation is that it is not likely to be stolen by unscrupulous employees.

" *Chemical Larvicides.*—(*a*) Paris green (copper aceto-arsenite). Following the publication by Roubaud (1920) of the results of his researches as to the value of paraformaldehyde powder as a larvicide, Barber and Hayne (1921) carried out experiments with various compounds of arsenic, of which paris green proved the most efficient. Since then it has been used widely in many countries, and it appears to come nearer to fulfilling all the requirements of an *Anopheles* larvicide than any other preparation at present available.

" Paris green (Schweinfurt green, Imperial green, Emerald green, Mitis green) is a micro-crystalline powder of emerald green colour, practically insoluble in water, but soluble in ammonia and in concentrated acids. Under United States law the name paris green is restricted to powders containing a minimum of 50 per cent. arsenious oxide, but in Europe the name is sometimes applied to substances containing green aniline dyes which are valueless for larvicidal purposes.

" Barber and his colleagues (1936) in Greece have described a dustless method of applying paris green, which has also been used in India (Russell and Jacob, 1939), in Cyprus (Aziz, 1939),

and in Russia (Keiris and Klokov, 1939; Yurchak and Bozhenko, 1939). A stock mixture is prepared, composed of kerosene oil 100 c.c., paris green 200 c.c. and dry powdered egg albumen 1 gramme,* which are poured into a Winchester quart bottle in that order. The bottle is vigorously shaken, a procedure which is repeated whenever any of the mixture is poured out. A number of corked vials are provided, into each of which 25 c.c. of the stock solution is poured, before the coolie sets out on his round. The vials are carried in a cartridge belt, which accommodates 20 to 25 vials, each in a separate pouch. The coolie also carries a tin can of one litre capacity, which, when not in use, is suspended from the belt, and a funnel provided with a wire gauze sieve.

"On arrival at the scene of operations, the coolie pours two litres of water into the sprayer from his tin can, filtering this through the funnel to remove debris. He then adds the contents of one vial, after vigorously shaking it, washing the last remnants of the stock mixture into the sprayer with a little more water. Three more cans full of water are added, making five litres in all to 25 c.c. of stock mixture. The tank of the sprayer is agitated from time to time by a sway of the hips during the application of the spray. One vial (i.e., 25 c.c.) of the stock mixture is sufficient for treating 700 to 900 square feet of water surface, and an average Indian coolie uses the contents of 20 to 25 vials per working day (Russell and Jacob, 1939; Russell, Knipe and Rao, 1940).

"The advantages claimed for this method are that there is no need to store or transport the diluent, that very little paris green is lost by sinking, as it is kept afloat by the kerosene, and that there is no dust left on the water surface to block the feeding of the larvæ; which last consideration may explain why so little paris green is found necessary, as compared with other methods of application. It seems likely that this technique may be found of great value in special circumstances, as for instance during the course of military operations.

"*Method of Action of Paris Green.*

"The particles are eaten by the Anopheline larvæ, which feed on the surface of the water, and the chemical acts as a direct poison. It is therefore important that the particles of paris green should remain floating on the surface for as long a period as possible. This is largely determined by the surface tension of the water. The more vegetation that is present in the water the greater is the surface tension, the longer do the particles float, and hence the greater is the efficiency of the paris green as an *Anopheles* larvicide. Experiments are being carried out by various firms with the object of producing a form of the chemical which will remain on the surface for the longest possible time.

"Paris green has no effect on the pupæ of mosquitoes, because these do not feed, nor, when applied in the usual way, does it affect the larvæ of Culicines, because these are not surface feeders. The very young (first day) larvæ of Anophelines are

* In Delhi, a mixture of kerosene oil ½ gallon, paris green 2½ pounds, castor oil 1 ounce and the whites of 4 to 6 eggs, shaken up in a petrol can and used in the dilution of 1 ounce to 1 gallon of water, has been found effective.

also usually unaffected, presumably because the particles of paris green are too large for them to eat. It is possible that this latter difficulty may be overcome by the production of an extremely fine form of the chemical.

"*Requirements of a Good Paris Green.*

"(i) It should be of a deep green colour.

(ii) It should contain over 50 per cent. arsenious oxide; a good quality averages 55 per cent.

(iii) Its solubility in water should not exceed 3 per cent.

(iv) It should be capable of being passed through bolting cloth of at least 200, preferably 300 mesh.

(v) Each batch should pass a practical field test before acceptance, for it has been found by experience that samples apparently identical vary greatly in toxicity to larvæ.

"Experiments have also been made with copper sulphate as a direct larvicide. Ross and Edie (1911) found that a dilution of 1 part in 500 was insufficient, whilst Hargreaves (1923) stated that a strength of 1 in 200 was necessary to kill all larvæ. It is of course out of the question to employ copper sulphate in this strength for general purposes. Miller (1920) in New Zealand has recommended its use in dilutions of 1 in 5,000, stating that it will kill larvæ and pupæ in that strength, and will not affect the water for drinking purposes; but in view of the opinions expressed by other workers this statement should be accepted with reserve.

"*Vegetable Larvicides.*—Decoctions and emulsions of various species of *Derris*, a leguminous plant, have been recommended for larvicidal use. These are poisonous to fish, and cannot be advocated for general use. Infusions of tobacco leaf, powdered pyrethrum and pellitory root have also been suggested as larvicides.

"*Larvicidal Fish—Requirements for.*

"(i) They must be small, so that they can get about in shallow water among weeds, etc.

(ii) They must be hardy, and flourish in both deep and shallow waters.

(iii) They must be able to breed freely in confined water areas.

(iv) They must be able to stand transport and handling.

(v) They must be difficult to catch, and able to escape their natural enemies, including man.

(vi) They must be absolutely worthless and insignificant as food.

(vii) They must be top-feeders and carnivorous.

"*Limitations of Fish in the Control of Mosquito Breeding.*

"There are certain disadvantages in the use of fish as a control measure:

(i) Fish are only effective if present in sufficient numbers.

(ii) They are only completely effective in the absence of all weed and floating debris.

(iii) Small boys can be relied upon to catch them if they get the opportunity.

(iv) Over-zealous persons are apt to introduce other and larger species which may prey on them.

(v) If there is not a sufficient food-supply for them, e.g. in wells, they will eat their own young, so that breeding places must be periodically re-stocked.

(vi) Constant inspection is needed to see that the fish are flourishing and are in sufficient numbers, and that the water is free from horizontal vegetation and floatage.

(vii) In order to carry out these inspections, and to keep up a sufficient stock of fish for the various breeding places, a special staff is necessary."

Summary of Control Measures.

" *Sprays.*—The spray-killing of adult mosquitoes is now recognized as a major control measure, and in the opinion of the author the development of this method represents the most important advance which has been made in malaria prevention in recent years.

" Swellengrebel (1934) and his co-workers in Holland have used the method for many years, but it was not adopted extensively in the tropics until the publication of the remarkable results achieved with pyrethrum sprays in rural areas in South Africa from 1932 onwards by Ross (1936), de Meillon (1936), Booker (1935). It has been widely used for controlling malaria in native huts in Natal and Zululand, and for the protection of railway and other employees, and has been found especially effective in combating outbreaks of malaria in epidemic form. Thornton (1933–36) has drawn attention to the fact that the effects are produced not by a diminution in the number of Anophelines, but by a reduction in their rate of infection, which may be very marked, a fact which has been confirmed by our experiences in India.

" Spray-killing of adult mosquitoes was brought into use in Delhi in 1936, when the quarters occupied by four communities of government employees, living in particularly malarious sections of the urban area, were regularly sprayed throughout the malaria season (Covell, Mulligan and Afridi, 1938). The results were so striking that the method was immediately recommended for use throughout India, as being particularly suitable for personnel such as police, railway, forest or other government employees, and labour forces on estates, mills and other industrial enterprises where housed in permanent quarters. It was at first thought that the usefulness of this method would be limited to such conditions, but in 1937 it was introduced as an experimental measure in two villages on the outskirts of Delhi. The results were so encouraging that it has since been extended to a number of other villages in Delhi Province.

" Reports on the efficacy of the spray-killing of adult mosquitoes from employers of labour, railway authorities and government officials from all parts of India have been universally favourable; and Russell and Knipe (1939) have reported that this method has had a marked effect in reducing malaria transmission in a typical South Indian village.

" The efficacy of the method is in direct proportion to the frequency of its application. In areas where the infection rate

among the carrier species of Anopheline is low, good results have been recorded by spraying once a week only. Where the infection rate is high, it is advisable to spray twice, or even three times, a week throughout the malaria season. It is seldom possible to spray more often than this on a large scale, but in very malarious localities residents should be encouraged to spray their living rooms and those of their servants daily while transmission is at its height, especially when a case of malaria has actually occurred on the premises, or in the immediate vicinity. Particular attention should be directed to the spraying of rooms occupied by young children and infants, who constitute the chief source of infection for mosquitoes.

"The spray should be mixed by a responsible person, to minimize the risk of theft. All apertures should be closed as far as possible before spraying, and should preferably remain closed for twenty minutes thereafter. Pieces of sacking, old blankets, sheets, etc., are useful for this purpose. If there are any cowsheds, stables or other attractive shelters for mosquitoes near by, these should be sprayed also.

"Regular spraying should be commenced when the local carrier species of mosquito begins to enter the houses, at least a fortnight before the malaria season is expected to start, and should be continued throughout the transmission period. The most suitable time of day for spraying is in the early morning, before cooking has commenced. The personnel employed should be recruited from among the local residents, and it is best to engage for this purpose boys of under fourteen years of age, as there is not likely to be any objection to their entering rooms occupied by women. The exercise of tact is necessary in introducing the method, but, once the routine has been established, it is invariably found to be extremely popular among the persons concerned. After a while it may be found possible to leave the actual spraying to the local inhabitants, but periodical supervisory visits are essential, for it is the universal experience of sanitarians that the individual, if left entirely to himself, will seldom lift a finger to safeguard his own health, or that of his family.

"Hitherto, the chief difficulty in applying the method has been the lack of a suitable type of sprayer. For small rooms, the hand sprayers or atomizers obtainable everywhere at a trifling cost are useful, but they are not very durable and are uneconomical in use. Far the most effective apparatus at present available is an ordinary power spray-painting machine, driven either by an electric motor or a small petrol engine. These are especially valuable for use in large buildings, such as barracks."

Some points of mosquito control, and of Anophelines in particular, need to be emphasized.

Fuel diesel oil is more efficient since it contains natural poisons and forms a better film and in addition costs less.

Swamps which are more or less overgrown with vegetation are not oiled, since, with the vegetation, it is impossible to obtain an unbroken film of oil on the water. It is more profitable to use the "wet" paris green method.

When oil is used on an "open" swamp the entire surface of the water must be oiled, and not just round the edges.

Those areas where the fish the Top Minnow (*Gambusia affinis*) is in use *must not be oiled, because the fish will be killed.*

Before any control methods are put into practice a survey must be made to see what Anophelines are present and if oil is to be used to make sure that the Top Minnow is *not* present for the above stated reason.

In training garrison camps the measures should be of a permanent character. That is, all swamps should be filled in, or if this is not practicable they should be drained.

The control of *Aëdes* (*Stegomyia*) *aegypti*, *Aëdes* (*Stegomyia*) *albopictus* and *Culex fatigans* is of a specialized nature and is placed under those species.

MOUNTING OF AND CARE OF COLLECTIONS.

The equipment necessary for mounting and housing dipterous specimens is as follows:

1. Entomological forceps; these must have good jaws.
2. A pair of straight-jawed forceps is useful.
3. No. 3 Kirby, Beard & Co.'s entomological pins.
4. Stainless steel pins, 0·056 thickness and 10 mm. long or the thinnest *pure* nickel pins may be substituted for large mosquitoes, but not for the small kinds.
5. Polyporus pith.
6. A good type X10 hand lens.
7. A Bishop Harman loupe is a decided acquisition, as it gives freedom of action for both hands.
8. An ordinary dissecting needle that has been bent to about an obtuse angle.
9. A small block of wood, about three by two inches by five-eighths of an inch, with a small hole or two along one side. This is used for raising the pinned mounts all to one height.
10. A piece of cork or cork composition to stick the specimens to after they are mounted and before they are transferred to the store box or cabinet.
11. Insect store-boxes. They are $10 \times 14 \times 3$ inches outside measurements. The best storage is in specially made cabinets with airtight drawers; these are expensive.
12. A supply of paradichlorbenzene. This is a slow-acting fumigant which protects cabinet specimens from damage by museum pests, of which we have some serious ones.
13. Beechwood creosote. The use of this prevents the growth of mold and is a very necessary adjunct in hot moist climates. Only a drop or two is necessary in a store box or cabinet drawer.
14. Some clean white blotting paper.

The polyporus pith is supplied compressed into narrow strips of varying length. This is cut into lengths of half an inch (an old safety razor blade is useful for this) and a fine stainless pin is passed through about an eighth of an inch from the end. It is a good plan to "pin up" a number of these polyporus pieces. Cardboard strips are bad because it is often necessary to turn the mounted specimen round, and with cardboard this cannot be done since the latter offers no resistance

to the pin, the result being that the hole becomes enlarged and no longer grips the pin. Celluloid has also been used, but this is objectionable for the same reason, and in addition it discolours badly with age. Polyporus does not discolour with age, neither does turning the specimen round enlarge the pin hole, as the pith grips the pin.

The next operation is to empty out, a few at a time, the mosquitoes from the killing bottle on to the white blotting paper, turn any specimens requiring it on their backs with the bent dissecting needle—mosquitoes must not be touched in any way with the hands—then pick up, with the entomological forceps, one of the pinned pieces of pith by the blunt end of the pin and transfix the specimen between the middle and hind pairs of legs, but do *not* push the pin right through the thorax: this may be prevented by giving the final push home against the thumb nail of the left hand. Next take the mount between the finger and thumb of the left hand and pierce the pith with a No. 3 insect pin and raise it to the required height by using the wood block. A specimen is *badly mounted* if (1) the *scales have been rubbed off the thorax*, or (2) the *pin shows through the thorax.*

The next procedure is to secure locality slips showing locality, state or country, collector's name and date. It is possible to have these printed in very small type, and one is transfixed on the No. 3 pin.

That is the whole process of mounting. It cannot be a hurried job, but must be done slowly and with care, otherwise valuable material will be rendered useless.

When mosquitoes have been bred out they must on no account be killed for at least twenty-four, and for preference, forty-eight hours. Should they be killed before that time they will shrivel so badly as to be rendered useless for cabinet specimens, because they will be distorted and cannot be identified with certainty. They should be kept away from light during the hardening period so that they will not fly about the cage unnecessarily and possibly rub off their scales.

So many of the diagnostic characters made use of in classification are found in the clothing, hairs, bristles, etc., that it is essential that specimens for determination be in perfect condition. The hairs and scales of the thorax are very readily rubbed off, therefore bred specimens are in better condition than the majority of captured "wild" ones, but the former must be allowed to harden properly, as noted above, before killing.

Preparation of Specimens for Identification.

Preparations of the male terminalia are made by cutting off the apex of the abdomen, soaking the cut portion in 70% alcohol for a few moments, then placing it into a small quantity of 5% sodium hydroxide in a 6 in. × 1 in. test tube and bringing gently to the boil. It is necessary to place a couple of bent pins or similar objects in the tube to prevent violent ebullition. Having boiled the specimen for a few moments, empty into an excavated block, cover and leave for seven to ten hours. When sufficiently clear transfer to glacial acetic acid for an hour or so then to clove oil until clear, then mount in *thin* Canada Balsam. The balsam must be thin, otherwise it is impossible to make a

satisfactory mount. *Do not wash the sodium hydroxide out with water.*

Larval Skins.—The skin of the fourth stage larva possesses all the characteristics of the larva and is much more convenient to handle and makes a far superior preparation when due care is taken in the handling. When it is desired to obtain such skins the larvæ, adult for preference, are placed in a 6 in. × 1 in. test tube with some of the food and water from the breeding basin. When the larva casts its skin to become a pupa the larval skin is found floating on the surface of the water. It is lifted from the water by means of a fine bore pipette and dropped into absolute alcohol. I have found that if skins are placed in 70% alcohol they are liable to twist. Two changes of short duration are sufficient. The skin is then mounted in the same way as the male terminalia except that Euparel and *not* Canada Balsam is used. Two drops of Euparel are placed on the tiny " slide " then the skin is carefully lifted across from the absolute alcohol, draining off excess of alcohol with a cut strip of *white* blotting paper, to the Euparel, arrange the skin *dorsal* surface upwards with fine dissecting needles, place on the coverslip. The preparation is then ready for examination.

No brush of any description must be used in the handling of larvæ or their skins, since irreparable damage will be done to the hairs and bristles of the specimens.

It is essential that these mounts be with the actual mosquito specimen. With that in view cut some square or oblong No. 1 coverslips with a writing diamond into pieces 10 × 5 mm. Each piece is fastened on to a piece of Bristol board with a small quantity of Canada Balsam, the overlap of Bristol board and coverslip being about 3 mm. Having arranged the specimen in the Canada Balsam, other pieces of coverslip are cut, about 5 × 3 mm. in size, and used as coverslips for the various mounts. The object of using the Bristol board is so that the specimen may be on the same pin as the adult by transfixing it through the cardboard with the mounting pin.

REFERENCES.

References marked † are mainly quoted by Covell (1941) and have only been seen in reviews by me: those marked * have not been seen by me but are quoted by Edwards (1941) and Bonne-Wepster and Brug (1932).

Aziz, M., 1939: Med. Dept. Papers Govt. Cyprus, No. 5.

Bacot, A. W., 1916: Yellow Fever Commission (West Africa). Report of the Entomological Investigation.

Barber, M. A., and Hayne, T. B., 1921: *U.S.A. Pub. Hlth. Repts.*, XXXVI, 49, 3027.

Barber, M. A., Rice, J. B., and Mandekos, A., 1936: *Amer. J. Hyg.*, XXIV, 4: *R.A.E.B.*, XXIV, 289.

Barnes, M. E., 1925: *Amer. Jnl. Hyg.*, V, 315.

Barraud, P. J., 1934: The Fauna of British India. Diptera, V.

Barraud, P. J., and Covell, G., 1927: *Trans. Far East. Assoc. Trop. Med.*, 7th Congress, III, 98. 1928: *Ind. Jnl. Med. Res.*, XV, 671.

Base, J. F., *et al.*, 1919: *U.S.A. Pub. Hlth. Bull.* No. 104, 137.

Beeukes, H., Keer, J. A., Weathersbee, A. A., and Taylor, A. W., 1933: *Trans. R. Soc. Trop. Med. Hyg.*, XXVI, 425.

Belding: Textbook of Clinical Parasitology, London, 1942.

Booker, C. G., 1935: Report Dept. Pub. Hlth. S. Africa, 1934-35, 79: *R.A.E.B.*, XXIV, 77.

Boyce, R. W., 1910: Mosquito or Man? London.

Brett, G. A., 1938: *Trans. R. Soc. Trop. Med. Hyg.*, XXXII, 113.

Bonne-Wepster, J., and Brug, S. L., 1932: *Gen. Tijds. Ned.-Indie*, Bij. 2.

Bryan, E. H., 1941: American Polynesia. Honolulu.

Bunker, C. W. O., and Hirschfelder, A. D., 1925 : *Amer. Jnl. Trop. Med.*, V, 359.
de Burca, B., 1939 : *Jnl. Mal. Inst. India*, II, 121.
Cardamitis, J. P., 1929 : *Bull. Soc. Path. Exot.*, XXII, 272.
Christophers, S. R., 1913 : *Ann. Trop. Med. and Par.*, VII, 45.
1915 : *Ind. Jnl. Med. Research*, III, 362.
1915 : *Loc. cit.*, III, 371.
1923 : *Loc. cit.*, X, 698.
1924 : *Indian Med. Memoir*. No. 3.
1933 : The Fauna of British India, Diptera, IV.
Christophers, S. R., and Barraud, P. J., 1924 : *Ind. Jnl. Med. Research*, XI, 1103.
1931 : *Rec. Mal. Surv. India*, II, 161.
Christophers, S. R., and Khazan Chand, 1922 : Report on Malaria Assam Estates and Factories Ltd., Nalbari, Assam, 1921. Calcutta.
Coogle, C. P., 1923 : *U.S.A. Pub. Hlth. Repts.*, XXXVIII, 10, 137 ; *loc. cit.*, No. 156, 136.
1927 : *Loc. cit.*, XLII, 16, 1101.
Covell, G., 1941 : Malaria Control by Anti-Mosquito Measures. Calcutta.
Covell, G., Mulligan, H. W., and Afridi, M. K., 1938 : *Jnl. Mal. Inst. India*, I, 105.
†Darling, S. T., 1910 : Studies in Relation to Malaria. Ed. 2. Panama Commission Publication.
Dover, C., 1930 : *Ind. Jnl. Med. Research*, XVII, 961.
Edwards, F. W., 1932 : Genera Insectorum, 194 Fasc., Diptera, Belgium.
1941 : Mosquitoes of the Ethiopian Region. London.
Faust, E. C., 1929 : *Jnl. Trop. Med. Hyg.*, XXXII, 133.
Ferguson, E. W., 1928 : Report Director-General Public Health, N. S. Wales, 1926, 154.
†Fermi, C., 1926 : *Riv. Mal.*, V, 286.
† 1928 : *Malariologia*, Ser. III, 6.
†Fletcher, T. B., 1912 : *Proc. 4th Entom. Mtg.*, Pusa, 219.
*Flu, P. C., 1928 : *Acta Leidensia*, III, 1. Quoted by Edwards.
Freeborn, S. B., and Atsatt, R. F., 1918 : *Jnl. Econ. Entom.*, XI, 299.
†Fry, A. B., 1922 : *Ind. Med. Gazette*, LVII, 1.
Gater, B. A. R., 1934 : Aids to the Identification of Anopheline Larvæ in Malaya.
1935 : Aids to the Identification of Anopheline Imagines in Malaya.
Giemsa, G., 1914 : *Archiv. Schiffs. Trop. Hyg.*, XVIII, 26 ; *R.A.E.B.*, II, 80.
Giemsa, G., and Muhlens, 1911 : *Loc. cit.*, XV, 533.
Giles, G. M., 1902 : A Handbook of Gnats or Mosquitoes. Ed. 2.
Ginsburg, J. M., 1927 : Proc. 14th Ann. Mtg. New Jersey Mosq. Ext. Assoc., 110.
Green, H. W., 1924 : *Amer. Jnl. Hyg.*, IV, 12.
Hackett, L. W., 1929 : *Trans. Roy. Soc. Trop. Med. and Hyg.*, XXII, 477.
Hacker, H. P., 1925 : Malaria Bureau Repts., F.M.S., III.
Hargreaves, E., 1923 : *Bull. Ent. Research*, XIV, 213.
Harris, R. Hamlyn, 1931 : *Ann. Trop. Med. and Parasitology*, XXV, 21.
Heydon, G. M., 1923 : *Med. Jnl. Aust.*, II, 625.
†Home, H., 1926 : The Engineer and the Prevention of Malaria. London.
†Howard, L. O., 1892 : *Insect Life*, V, 12, 109 and 199.
James, S. P., 1914 : *Ind. Jnl. Med. Research*, II, 240.
*James, S. P., Da Silva, W. T., and Arndt, E. W., 1914 : Report on a Mosquito Survey of Colombo, Colombo. Quoted by Edwards.
*Kazeeff, W. N., 1925 : *La Nature*, LXIII, No. 1, 23. Quoted by Edwards.
†Keiris, L. M., and Klokov, N. A., 1939 : *Med. Paras.*, VIII, 303 ; *R.A.E.B.*, XXVIII, 37.
King, F. H., 1922 : Irrigation and Drainage, Ed. 8. New York.
†Kligler, I. J., 1925 : *Trans. 1st Inter. Cong. Malaria, Rome*, 149.
Knowles, R., and Senior-White, R. A., 1927 : Malaria : Its Investigation and Control, Calcutta.
Lang, W. D., 1920 : Hand. Brit. Mosquitoes, London.
Leak, W. N., 1921 : *Jnl. Trop. Med. and Hyg.*, XXIV, 37.
Lefroy, H. M., 1907 : A Preliminary Account of the Biting Flies of India. Government Press, Calcutta.
*Liston, W. G., and Akala, T. G., 1913 : *Proc. Gen. Mal. Commission, Madras*, 1912, 187. Quoted by Edwards.
McFarland, J., 1928 : *Jnl. Amer. Med. Assoc.*, XCI, 2014.
MacArthur, W. P., 1923 : *Jnl. Roy. Army Med. Corps*, XL, 1.

Mackerras, Ian M., 1927 : *Proc. Linn. Soc. N. S. Wales*, LII, 33.
Marshall, J. F., 1938 : The British Mosquitoes, London.
*Mathis, M., 1934 : *C.R. Soc. Biol.*, CXVII, 878.
1935 : *Bull. Soc. Path. Exot.*, XXVIII, 577.
†De Mellon, B., 1936 : *Quart. Bull. Health Organ, L. of N.*, V, 134 ; *R.A.E.B.*, XXIV, 153.
Miller, D., 1920 : New Zealand Dept. Pub. Health Publication No. 3, 14.
Mumford, E. P., 1942 : *Jnl. Trop. Med. and Hyg.*, XLV, 74.
Nuttall, G. H. F., and Shipley, A. E., 1902 : *Jnl. Hygiene*, II, 73.
†Orenstein, A. J., 1914 : *Archiv. Schiffs. Trop. Hyg.*, XVIII, 16.
Overbeek, J. G., and Stoker, W. J., 1938 : *Meded. Dienst. Volks., Ned.-Ind.*, XXVII, 183.
1938 : *Jnl. Malaya Br. Brit. Med. Assoc.*, I, 281.
Parsons, A. C., and Brook, G. R., 1919 : *Jnl. Roy. Army Med. Corps*, XXXII, 1.
Patton, W. S., and Evans, A. M., 1929 : Insects, Ticks, Mites and Venomous Animals of Medical and Veterinary Importance, Part I.
†Peterson, J. P., and Ginsburg, J. M., 1929 : *Proc. 16th Ann. Mtg. New Jersey Mosq. Ext. Assoc.*, 92.
Prince, J. A. Le, 1915 : *U.S.A. Pub. Hlth. Reports*, XXX, 536.
Puri, I. M., 1931 : *Indian Med. Research Memoir*, No. XXI.
Richmond, A. E., and Mendis, J. C., 1930 : *Rec. Mal. Surv. India*, I, 205.
†Rizzi, M., 1919 : *Ann. d'Igiene*, XXIX, 748 ; *R.A.E.B.*, IX, 131.
Rook, H. de, 1924 : *Geneesk. Tijds. Ned.-Ind.*, LXIV, 642.
†Ross, G. A. P., 1936 : *Quart. Bull. Hlth. Organ, L. of N.*, V, 114 ; *R.A.E.B.*, XXIV, 153.
Ross, R., 1911 : *Jnl. Trop. Med. Hyg.*, XXIX, 150.
Ross, R., and Edie, E. S., 1911 : *Ann. Trop. Med. Paras.*, V, 385.
†Roubaud, E., 1919 : *Bull. Agric. Alger-Tun-Moroc*, XXV, 272 ; *R.A.E.B.*, VIII, 33.
Russell, P. F., and Jacob, V. P., 1939 : *Jnl. Mal. Inst. India*, II, 261.
Russell, P. F., and Knipe, F. W., 1939 : *Loc. cit.*, II, 229.
Russell, P. F., Knipe, F. W., and Rao, T. R., 1940 : *Ind. Med. Gazette*, LXXV, 740.
Senior-White, R. A., 1928 : Studies in Malaria as it Affects Indian Railways. Government Press, Calcutta.
Shannon, R. C., and Davis, N. C., 1930 : *Amer. Jnl. Trop. Med.*, X, 151.
Shannon, R. C., and Putnam, P., 1934 : *Proc. Ent. Soc. Wash.*, XXXVI, 185.
Siler, J. F., Hall, M. W., and Hitchens, A. P., 1926 : *Phil. Jnl. Sci.*, XXIX, 1.
Soewadji Prawirokardjo, 1939 : *Geneesk. Tijdschr. Ned.-Ind.*, LXXIX, 1691 ; *R.A.E.B.*, XXVIII, 4.
†Stendel, 1911 : *Arch. Schiffs. Trop. Hyg.*, XV, 121.
Svensson, R., 1940 : Handbook Malaria Control, London.
Swellengrebel, N. H., 1934 : *Geneesk. Tijd. Ned.-Ind.*, LXXVIII, 345 ; *R.A.E.B.*, XXII, 116.
Swellengrebel, N. G., and Rodenwaldt, E., 1932 : *Die Anophelen Niederlandisch-Ostindien, Jena.*
†Symes, C. B., 1930 : *Kenya and E. Africa Med. Jnl.*, VII, 2.
Taylor, F. H., 1929 : *Trans. 7th Cong. Far Eastern Assoc. Trop. Med., Calcutta*, III, 143.
Thiel, P. H. van, 1939 : *Riv. Mal.*, XVIII, 95 ; *R.A.E.B.*, XXVIII, 10.
*Toumanoff, C., 1937 : *Bull. Soc. Med.-chir. Indochine*, XV, 964.
Walch, E. W., 1932 : *Geneesk. Tijds. Ned.-Ind.*, LXXII, 682 ; *T.D.B.*, XXXI, 158.
Walch, E. W., and Bonne-Wepster, 1929 : *Geneesk. Tijds. Ned.-Ind.*, LXIX, 167.
Walker, E. L., and Barber, M. A., 1914 : *Phil. Jnl. Sci.*, IX, B, 381.
*Wanson, M., 1935 : *Ann. Soc. Belg. Med. Trop.*, XV.
Watson, M., 1921 : The Prevention of Malaria in the Federated Malay States, Ed. 2, London.
Williamson, K. B., and Rajamoney, P. D., 1928 : *Malayan Med. Jnl.*, III, 88.
†Wilson, C. J., 1930 : Ann. Rept. Malaria Advisory Board. 1929, Supp. *F.M.S. Govt. Gazette*, August 29.
Woke, P. A., 1937 : *Jnl. Parasitology*, XXIII, 310.
Woodhill, A. R., Pasfield, G., 1941 : *Proc. Linn. Soc. N. S. Wales*, LXVI, 201.
†Yurchalk, F. F., and Bozhenko, V. P., 1939 : *Med. Paras.*, VIII, 170 ; *R.A.E.B.*, XXVIII, 7.
Zetek, J., 1916 : *Ann. Ent. Soc. America*, IX, 275 ; *R.A.E.B.*, V, 1.

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